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ON

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4. *The primary conditions: as produced in nature.*—The essential conditions of the phenomenon are fulfilled whenever a body of water confined in an inclined channel, of whatever dimensions, is arrested or retarded by a total or partial obstruction in its progress to its point of discharge, so as to be pressed back above that level; a state of permanence being attained when the increase of pressure so produced causes a discharge equal to the supply of water at the upper end, or when overflow takes place there. These conditions are produced continually in nature by the ordinary process of formation of sedimentary rocks, independently of any turning up of the strata either from the original *form* of the floor of deposition or by subsequent disturbance. Even in an open water basin the formation of strictly horizontal deposits is a very exceptional occurrence, for there is always greater deposition on the side from which the sediment is derived. It is similar in the case of deposits formed above water level by the action of rain and rivers, of which we have such extensive instances in India; accumulation takes place most rapidly in the border zone where the denuding action of these agencies changes into one of deposition; and thus do alluvial plains present a constantly increasing slope from the sea-margin to the foot of the uplands whence their materials are derived. In this way the first condition of artesian springs is established originally in all sedimentary rocks, in the prevailing slope of deposition; subsequent disturbance would generally increase this condition of slope or 'fall.' The other conditions are also often aboriginally provided for in stratified rocks: in the distribution of coarse and fine deposits by alternation, or by the latter covering the former, the confined water channel is produced; and the usually greater accumulation of the coarser materials at and near the higher marginal zone of the so-called basin ensures the retarded discharge and the consequent accumulation of water at a higher level, which is the active factor in artesian springs.

5. *Experimental illustrations.*—The foregoing statements may be made plain by the following experimental facts.[1] A leaden pipe of half inch bore and about 7 feet long was placed on an inclined board, raised 15 inches at one end, making a slope of about 10 degrees, as shown in figure 1 of the annexed plate. Arrangement was made for a constant supply of water, according to demand, at the upper end. At intervals of about 19 inches from the lower end of the pipe, holes were made on the upper side, in which glass tubes were fixed, reaching to the height of the upper end of the pipe. In the free pipe so placed, with a full supply of water at the upper end, there was a discharge of 322 cubic inches per minute. The pipe was then filled with small shot (No. 8), and the feed water being kept strictly level with the surface of the shot at the top, there was only a discharge less than 5 cubic inches per minute. In neither of these cases, *i.e.*, while the pipe was quite straight, whether with the water rushing through the free pipe or slowly percolating through the shot, was there the slightest tendency of the

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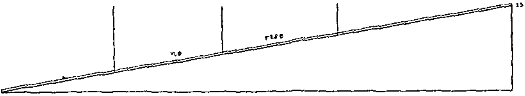

Fig 1 Pipe filled with small shot

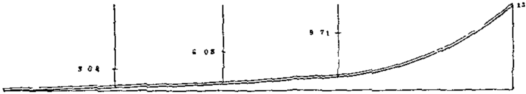

Fig 2 Pipe filled with small shot

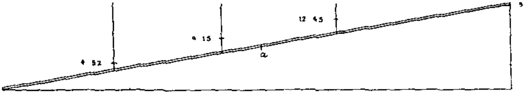

Fig 3 Pipe with small shot below a and large above a

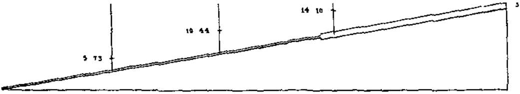

Fig 4 Pipe filled with small shot

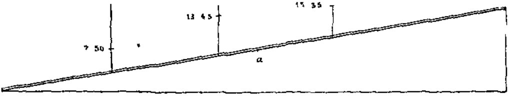

Fig 5 Pipe with small shot to a none above a

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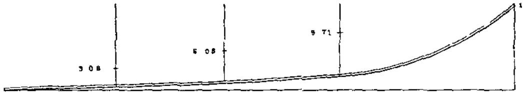

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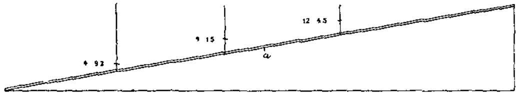

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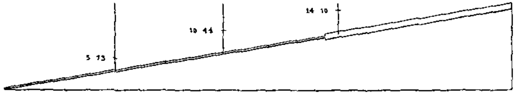

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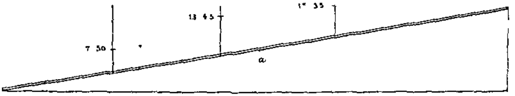

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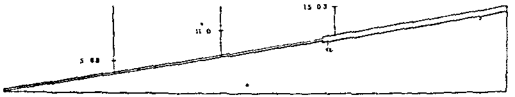

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water to rise in the glass tu [illegible] were the same at every point of [illegible] pres- sure, or *vis a tergo*, produced [illegible] Now [illegible] that the discharge of the pipe depends upon three factors—its [illegible] the pipe, and [illegible] the following experiments The pipe was bent at the upper end, giving it a gradually decreasing slope to near the third tube Shot (No 8) was again filled in, as in the preceding experiment, and water laid on and maintained at the exact upper surface of the shot, when a considerable rise took place in the three glass tubes as represented in [illegible] to a natural scale of about $\frac{1}{20}$th[1] [illegible] the rises that would take place in [illegible] only change in this experiment from the previous one is the increased poten- tial discharge in the upper part of the tube owing to increased slope; this flow is obstructed and retarded [illegible] and thus a pressure, or *vis a tergo*, is produc[illegible] the rise in the several tubes. In th[illegible] hat this condition of increased slope towards the [illegible] in the formation of sedimentary rocks The next experiment (case No 3) shows the effect of unequal porosity, all else being as in case No 1. The pipe was charged with No 8 shot to between the first and second tubes, and then filled up with much larger shot (BB) The rises that took place are [illegible] checking of the greater poten- [illegible]

[illegible] the pipe. [illegible] the finer material being swept on to the lower or more distant position. [illegible] show the independent effect of a change of capacity in the water stratum, a pipe of 1 inch bore was joined to the smaller pipe, between the first and second tubes, and the whole compound pipe filled with the small shot (No. 8), as in case No 1. The effect, shown [illegible] than in case No. 3, no doubt in exact propo[illegible] discharge of the one-inch pipe charged with N[illegible] length of half-inch pipe filled with BB shot. [illegible] a normal result of the process of rock formation, [illegible] coarse materials at the upper margin of deposition would give a vastly greater sectional area to the water strata in that position, thinning out inde- finitely beneath the finer succeeding deposits Numerous other experiments were made, from which I select two. one to show the extreme limit of con- dition No 3; the upper part of the pipe was left free of shot, when the rise in the tubes was, of course, very great, as shown in figure 5. The combined effect of cases 3 and 4 are shown in figure 6, when the larger pipe was filled with BB shot.[2] As occurring in nature these several conditions

[1] It is interesting to observe that in this experiment the line joining these heights is straight, and that its prolongation intersects the two terminals of supply and discharge. This fact was confirmed when the head was raised to 20 inches and lowered to 10 inches, so, within the range of these experiments, it indicates a law of the conditions.

[illegible] to a constant head level) are recorded, [illegible] a rise in the upper tube, actually [illegible] to nearly four tenths of an inch. In this experiment the feed was managed by a [illegible] regulated by a pinch-cock, from a water surface about 4 inches higher than the top of the pipe, the lower end of the [illegible] being close on the surface at the top of the pipe, the increased rise in the tube was evidently due to the continuous impact of the tiny jet of water by which the feed was sus- tained. To [illegible] this interference an intermediate cistern was introduced, having an overflow to ensure a constant surface at about 1 inch over the top of the pipe, but even with this arrangement the effect was still observable, as in case 6.

are of course almost infinitely varied, and beyond all possibility of accurate detection from the surface; but throughout every complication the total result must rigourously conform to the laws indicated in the foregoing experiments.

6. *Practical difference between basins of disturbance and of original deposition.*—The simplicity of the primary conditions that have been shown to govern the action of artesian wells might lead to very false expectations as to the ease and certainty with which such wells may be established. It needs some knowledge of geology to be aware of all the chances that may intervene to frustrate the best laid hopes, and how those hopes have in the first instance to be based upon inferences that are far short of certainty. In this respect there is much difference in the data of observation between the two classes of sources I have indicated, those entirely dependent upon original conditions of deposition, and those which are largely due to subsequent disturbances of the strata. In the latter case it would seem as if additional complications were introduced: and to a certain extent this is true, for such strata are affected by fissures and dislocations from which difficulties the undisturbed deposits are free. But on the whole there is a balance of available information in favour of the more complicated structure.

7. *Examples.*—The contrast can be illustrated from familiar examples. The strata from which the deep artesian sources of London and Paris are derived are turned up and exposed in the country surrounding the valleys of the Thames and the Seine. The sequence of the strata on both sides can thus be observed and compared, and a fair opinion formed as to the water-bearing strata, and as to the depth at which they will be found within the basin. It is obviously different from deposits that still lie in their basin of formation. Here only the topmost beds are visible, and we can have no actual particulars, unless by trial sinking, as to the composition and depth of what lies below the surface. It is quite certain, however, that on the whole they are made up of alternations of porous and non-porous materials; and in the case of river valley deposits there is a further presumption that the bottom beds, formed largely of the debris of local rocks, would be coarse and porous, while, as the deposits accumulate and spread at higher levels, finer sediment would predominate: one might travel over the plains of India, from the delta of the Ganges to that of the Indus, without finding a transported pebble larger than a pea. Accordingly, it is a matter of very wide experience that artesian springs are abundantly yielded by such recent deposits. Those of Lombardy, of the Sahara and of Pondicherry are of this nature.

8. *Older rock-basins in India.*—There are in India several large areas occupied by old formations having a general synclinal disposition. This distribution of the rocks in isolated basins is quite a general feature of Indian geology, and it cannot be asserted as impossible that there should be artesian sources within some of these basins. In the south there are the Kadapah, Kaládgi, and Bhima areas in which the strata dip inwards from a rim of gneiss, but the rocks are too much indurated to be properly porous, and the frequent local contortions within the basin would otherwise disturb any calculation as to the continuity of any particular group of beds. In the north there is the great area of Upper Vindhyan rocks, stretching from Behár round by Ságar to Dholpur. The composition of the series, in thick alternating masses of sandstones and shales, presents the most favourable original conditions for the retention of underground water; and the lie of the strata is equally propitious, with a gentle inward slope on all sides. But here again the rocks are in too advanced a state of induration; none of them are porous in the degree required for a prolific water stratum, so

that, unless the supply were aided by fissures or other accidents, it could scarcely be counted upon. A more direct cause of failure at many points of the area would be found in the elevated position of the rock basin, which is orographically a plateau. Thus although the outcrops of the several lower groups on the borders of the area are higher than much of the surface in the centre, most of the rivers drain across the northern scarp in deep gorges or cañons, which would afford a natural outlet for percolation from those groups at a lower level than the upland plains.

9. *Secondary rock basins in India.*—Some of the objections made in the case of the older rocks would not apply with the same force to the great series of secondary rocks known as the Gondwana system. This also is distributed throughout the northern half of the peninsula, in more or less isolated basins, partly of original limitation, but a good deal affected by subsequent compression. It is composed largely of massive sandstones with subordinate clays, all in a much less advanced state of consolidation than are the Vindhyan rocks, but greatly more compacted than the upper secondary strata from which the deep artesian springs of the London and Paris basins are derived. The least permeable beds are, however, those at the base of the series. Although these generally include a great conglomerate, the 'boulder bed' of the Talchir group, supposed to be in some degree of glacial formation, the matrix of this bed is a fine silt, quite impervious to water. Still, in certain positions it is not impossible that artesian springs might be forthcoming in these rocks thus in a south ... ated below ... water that ... on may be noticed in the interior valley along the northern edge of the Satpura basin, where the Denwa clays are supposed to be underlaid by an attenuated extension of the Pachmari sandstone, which rises into high hills immediately to the south. I mention this ground because partial trials were made here in the borings for coal at Khapa and Manegaon, the former to a depth of 720 feet, the latter to 420 feet. But in neither case did any water rise to the surface, although in the Khapa hole an ingress of sand and water under pressure occurred at some points, necessitating the use of piping to a depth of 270 feet. It is rather to be hoped that no such store of water does exist in these deposits, as it would be a serious obstacle to deep mining, which may at some future time be undertaken. I am unable to quote any instances of an artesian boring in rocks that had undergone a considerable degree of induration. This state almost precludes the conditions required for artesian springs: porosity in an adequate degree can hardly exist, and the water circulation is relegated to cracks and fissures which affect the indurated impervious beds as well as the originally porous ones, so that the water distribution becomes promiscuous instead of in sheets.

10. *Inquiries made in Madras in 1864.*—In 1864 anxious inquiries were made by the Government of Madras as to the prospect of artesian borings in certain districts especially liable to drought, as specified in the subjoined letter:—

"From Secretary to the Board of Revenue, to Secretary to Government, dated Madras, 25th April 1864.

"SIR,—I am directed by the Board of Revenue to submit, for the consideration of Government, that it is expedient to make a thorough trial of the artesian well system in such parts of the country as, in communication with the Geological Survey Department, may be deemed most favourably circumstanced for the purpose.

"The actual and serious deficiency of water for drinking and domestic p[illegible] becomes painfully conspicuous in a season of drought such as the present, and [illegible]

as the Board can judge, the evil is greatest in localities which hold out fair promise of success to the proposed experiment.

"They may instance Coimbatore in the neighbourhood of the Neilgherry range, Bellary not far from the Ramandroog range, and parts of Kadapah, which are generally in sufficient proximity to hilly tracts to indicate *primâ facie* that the system might succeed.

"The Collectors could point out to the Geological Department the exact spots where the want of water is most keenly felt, when in the hot and dry season villagers have daily to travel some miles to obtain drinking water, and not unfrequently have to pay for it to the fortunate possessor of a spring, small tank, or well; and the Board believe that the Geological Surveyors could without much labour determine whether the contour and stratification of the country allowed hope of success for artesian wells."

In two of the districts mentioned, the hills, which were pointed out as possible sources of artesian springs, are entirely, as well as the ground beneath the plains, of crystalline metamorphic rocks. In the third the rocks are slates and quartzites of the transition series, in which the prospects are scarcely better. In connection with these inquiries two deep borings were recommended by Captain F. Fischer, R.E., to be made in the Bellary district, and the work was sanctioned by the Madras Government;[1] but they were not carried out from want of funds.[2]

11. *Borings in tertiary rocks at Gogah, Guzerát.*—The only artesian boring in India in rocks older than the alluvium that I can find mention of is one at Gogah (Gogo), a little promontory in the Gulf of Cambay, on the east coast of Kattywar, in Guzerát. It was put down in upper tertiary rocks, the same as those so well known for their fossil mammalian remains in the Island of Perim, 6 miles distant to the south-east. A notice of it is recorded in the Journal of the Asiatic Society of Bengal for 1837 (Vol. VI, p. 786), by the officer in charge, Lieutenant George Fulljames, presumably the originator of the enterprise. A full section of the boring is given, to a depth of 335 feet, the work being then in progress, but so far without result.[3] The section in the boring is not altogether unfavourable; in the lower portion there is a great preponderance of "stiff blue clay," which would form a thorough cover for any water-bearing bed below it; but there seems little or no prospect of success in such a position, at least from the tertiary beds themselves. These lie flatly, or with a gentle easterly slope of original deposition, but they are only a fringing belt on the Katty-

[1] Order No. 1895, dated 14th October 1864.

[2] Proceedings, Government of Madras, No. 138, dated 14th January 1865.

[3] My inquiries as to any further knowledge of this boring has elicited the following interesting information from the Public Works Secretariat, Bombay, dated 29th June 1881:—

"In reply to your letter No. 162, dated 12th May 1881, I have the honour to state that Lieutenant Fulljames' report cannot now be traced, but that it appears that from 1831 to 1837-38, an outlay of Rs. 65,163 was incurred in boring experiments in Guzerát, Kolaba, the Southern Maratha country, and Poona.

"As regards the experiments in Guzerát, the Collector of Ahmedabad in a report, dated 14th March 1842, stated as follows:

"'With respect to the advantages which have hitherto attended the experiments, I take this opportunity of observing that, although a moderate supply of sweet water may generally be obtained by this means in the Dholka purgunna, and undoubtedly in years when the monsoon fails and water is not procurable under any circumstances, the benefit to those villages where a bore has been successful cannot be too highly appreciated, yet on the whole I am of opinion their success cannot be considered to have been commensurate with the expense, including the risk of failure which attends them.'

"At Poona the operations were discontinued in consequence of the little prospect of success arising from the unfavourable nature of the strata. At Kolaba also the attempt proved an entire failure.

"Further search will be made for Lieutenant Fulljames' report, and if forthcoming copies will be duly transmitted to you."

for
rap,
sup-
ply from drainage is also very restricted, for at about 12 miles from Gogah the trap forms a small range rising to a summit of 986 feet The bedding in this rock is either horizontal, or, probably having a low westerly inclination The rainfall, moreover, is small, seldom exceeding 20 inches All things considered, the best chance of an artesian spring at Gogah would seem to be the possibility of a supply in the bottom beds, derived from the trap, or, more remotely still, from the opposite side of the basin of deposition, 50 miles to the east, where lower tertiary strata rise to some little elevation at the base of the Rájpipla hills, formed of the Deccan trap These two suggestions illustrate the considerations that may, as a last resource, be taken into account in speculating upon artesian sources

12 *Alluvial plains*—The want of water is nowhere more felt than in parts of the great alluvial plains of India, and all the deep borings in Northern India have been made in that region None other offers such a fair prospect of success although hitherto the results have been disappointing The plains are correctly spoken of as alluvial as being still more or less subject to increase from inundation or atmospheric action, but these surface deposits are often in continuous sequence with similar underlying strata of great thickness, and, no doubt, ranging in age to early pleistocene times These alluvial areas may be distinguished as of two kinds there are extensive upland valley plains, entirely encompassed by hills or low rocky outcrops, and the plains of the great rivers terminating on the seaboard

13 *Midland plains the Narbada Valley surface features*—Of the midland plains we have a good example in the country known as 'the Narbada Valley, in the centre of the peninsula, stretching for about 200 miles between Jabalpur and Harda, with a width of about 20 miles. The elevations of these two places are 1 351 51 and 946 75 feet [1] giving a total fall of a little over 400 feet, or about 2 feet per mile The cross section of the valley equally indicates that its surface is due to actual, or very recent alluvial conditions although the main river, the Narbada, enters the valley from the southern hills, at the east end its course throughout the valley keeps near to the northern side, a fact no doubt connected with the much greater influx of detrital matter from the south The watershed on the north is along the Vindhyan scarp, immediately overhanging the valley, while the southern affluents of the Narbada drain a large area of the Satpura range, composed of much softer rocks than the Vindhyans On the branch line to the Mohpani coal field there is a fall from 1,242 feet, at the foot of the southern hills, to 1,157 72 at Gadarwara junction, in a length of 11 miles, or about 7 feet per mile

14 *Recent erosion and its cause*—Although the deposits of the Narbada valley are the work of the existing rivers we have to note this primary result as completed, so far as the chief rivers are concerned, and as having already undergone modification of a most important kind as regards artesian springs The Narbada and all its main affluents now flow in permanently defined channels well below the general surface, and never inundate the adjoining p
unless in
mode of ac

[1] These elevations were kindly given to me by Mr J H Edwards District Engineer, G I P Railway, at Jabalpur, they refer to the level of the rails above mean sea datum level.

power, in the annual discharge of water; and this may be due either to an increased fall, or to an increased volume of water, or to a change in the regulation of the same total discharge from a distributed gradual escape, largely by percolation, to one taking place in concentrated floods. It is scarcely doubtful to which of these causes the actual conditions are to be assigned. An increased fall, whether by a lowering of the level of escape, or by a rise of the area of supply, would almost surely be detectable in the inequality of its effects at different points of the basin, either in the work done by the main river or of its affluents on either side; whereas the observed conditions of recent erosion occur about equally all over, where each stream enters the valley, as much as at the final point of discharge. The second cause may also be laid aside; there is nothing to support the supposition of a great increase of rainfall in late times. There is much reason to think that the effect under notice is attributable to the third cause mentioned, the increased rapidity of escape of the periodical rainfall, this being due to the progressive deforesting of the land since prehistoric times with increase of population. The effect of this upon artesian springs will be mentioned presently.

15. *Underground features of alluvial valleys.*—If we now attempt some conjectures as to the underground conditions upon which the chances of a water supply so much depend, we are at once confronted by the obscurity mentioned in *para.* 6. A first presumption regarding an alluvial valley is that it had under other conditions been excavated by the agencies which are now filling it up, the change of operation having been effected either by a suitable movement of the ground, or simply by the backward growth of deposits from the delta. Under this latter simplest, and perhaps commonest, *condition* of *alluvial* deposition, one assumption can be made regarding the depth of the deposits, that the maximum depth in any cross-section is less than that of any cross-section below it (down-stream), *i.e.*, that the alluvial area is not a 'rock-basin'—one in which the bottom of hard rock is cup-shaped, with interior depths greater than the lowest point of the enclosing barrier.[1] But this relative information is of no practical value without a knowledge of the maximum depth at any cross-section. A further uncertainty arises from the great irregularity of surface-form produced by subaerial denudation, according to the texture and posture of the rocks acted on. For instance, the upper valley of the Damuda, between the gneissic plateaus of Ránchi and Hazáribágh, is chiefly occupied by detached basins of Gondwána strata, which the river and its affluents have carved into hills of various shapes, leaving some central masses of sandstone nearly as high as the adjoining uplands of metamorphic rocks. If this valley were to become filled with alluvium, the future well-sinker might think himself safe in choosing a central position for his boring; and at many places he might sink successfully to a depth of several hundred feet, whereas not far off, in what he might think more open and safer ground, his rods would strike rock near the surface, on what are now the Lagu and the Maudi hills of Gondwána sandstone. Thus, to return to the actual case of the Narbada valley, the fact that outcrops of rock only occur near to the north or south boundary gives very small presumption as to the depth of the deposits at any point.

16. *Exemplified by the Narbada Valley.*—Other causes besides the simple ones just mentioned, and more local in their effects, may have contributed to bring about the formation of an alluvial basin and to complicate the underground features. The Narbada valley would seem to be a case in

[1] This is, of course, only true generally, and within moderate limits, for it is common to find in river beds a deep pool above a rock barrier; where soft or decomposable rock occurs above that forming the barrier; and it would be difficult to assign a limit to this action.

point; its history is evidently very [illegible] and as yet [illegible] worked out, but it will serve to illustrate the point [illegible]. The alluvial area occurs where the river valley lies between Vindhyan rocks on the north, forming the plateau of Malwa, Bhopal and Saugor, and Gondwana rocks on the south, forming the highest portion of the Satpura range. It is thus at once evident that we are in the neighbourhood of important structural features, that the valley here is not simply one of erosion in the same geological formation. The severance of these two great sedimentary series on opposite sides of the valley is complete, no remnant of either being found near the other, and it is doubtful if they were ever in contact in this region. They both rest with total unconformity upon the same transition and gneissic rocks, which are seen at a few places on the borders of the valley and might thus appear to form the bed of the alluvial basin. Both the Gondwanas and the Vindhyans, within their respective areas, have undergone comparatively little disturbance; but on the margin of these areas, i.e., next the valley, there is much local contortion in each of them. This circumstance has given rise to speculation as to the present limits of the sedimentary formations being due to great movements of downthrow, to the [illegible] south on the side of the [illegible] ground now occupied by [illegible]. Closer examination has not confirmed this view: at several points the upper beds of the Gondwana series are found lapping round the low hills of metamorphic rocks on the margin of the valley, proving that the original limits of the deposits were approximately where we now find them.[1] The case is not so clearly made out for the Vindhyans, but the fact that the shales which form a [illegible] [illegible] of the series within the basin are scarcely, if at all, represented along the southern margin, points strongly to [illegible] as on the Gondwana boundary. On this view then [illegible] that in Vindhyan, and still later in Gondwana times, there [illegible] of country where now lies the Narbada valley [illegible] less embarrassing than the former supposition of [illegible] of equal magnitude in still later times. [illegible]

[illegible]

Vindhyan plateau in Lower Bundelkhand. That area had certainly been occupied by hills of gneiss when the Vindhyans were deposited,[1] and it is equally certain that at the Deccan trap period it had been reduced to about its present level, the basalt being found in the low ground continuous with that on Vindhyans of the Ságar plateau (*l. c.*, p. 16); and that result was chiefly, if not wholly, due to simple weathering (*l. c.*, p. 95). We might then suppose that the same had occurred in the case of the Narbada valley, and that its re-excavation in the basaltic rock, on the old lines, was simply the effect of denudation. There would be nothing very forced in such a supposition, and, indeed, to a great extent it has to be adopted, but there are other facts that would not thus be accounted for.

18. *Continued: the Sukakheri and Gádarwára borings.*—The facts just referred to could not have been discovered from any observations at the surface; they have been brought to light by some trial borings for coal. It was conjectured that the Gondwána coal measures might have extended into valleys of the metamorphic hills, which formed the general boundary of the basin in this position, and borings were undertaken in the alluvium in front of the Mohpáni coal-field, one at Sukakheri, 3 miles from the hills, and one at Gádarwára junction, 11 miles from the hills. The latter was sunk to a depth of 251 feet, and the former to 491 feet, altogether in alluvial deposits. The operations could not be carried further, and practically they answered the purpose for which they were undertaken, for it would scarcely be profitable at present to sink for coal through such a thickness of soft rock; but, of course, it still remains unknown what formation underlies the valley deposits at these points. The discovery of the great depth of the alluvium is, however, in itself a very interesting and unexpected fact, as showing that the alluvial basin of the Narbada valley is a rock-basin of considerable depth. The rock-bed of the Narbada at Hindia, a few miles north of Harda, may be about 100 feet lower than the surface at Harda; and thus it would be nearly 150 feet higher than the bottom of the bore-hole at Sukakheri (where the rock had not yet been touched), at a point 115 miles higher up the valley; and it cannot be assumed that the Sukakheri boring chanced upon the deepest point of the alluvial deposits. It may thus be fairly presumed that special subsidence contributed to the formation of the valley; and this contribution must have been made at a comparatively recent date, for it is introduced to account for the depression of the actual rock-surface beneath the alluvial covering. Direct observation gives support to this supposition. Although, indeed, we find (as at Mohpáni) the basalt resting upon crushed and denuded lowest Gondwána beds close in front of the cliff of Upper Gondwána sandstone—showing that much of the disturbance and erosion affecting this formation had taken place before the Deccan trap period—yet there are numerous sections on the line of the southern edge of the Narbada valley to show that the trap *itself* has undergone much displacement in that position.

19. *Continued: special obstacles to artesian springs.*—So much then for the geological discussion of the facts; we may now look to their bearing on the artesian well question. We are assured of a basin of quite unexpected dimensions, and most of the surface conditions seem favourable, yet in two borings of very considerable depth no sign of an artesian spring occurred. This would, indeed, be fully accounted for by the fact that neither boring passed through or touched any bed of porous material. An occasional pebble was brought up, but the whole mass passed through seems to consist of more or less impervious clay. I find it recorded in the boring journals that the hole had partly filled up again and had to be cleared out, but this

[1] Manual of Geology of India, p. 87.

seems to have occurred where the rods were far (sometimes 50 feet) ahead of the tubing, a fact in itself sufficiently proving the tenacity of the ground. We might then consider the question as unaffected by these experiments, but I think I can point out a circumstance which would, independently of the condition of a porous water-stratum, prevent the occurrence of an artesian spring at the general surface level of such a valley as this, which is, I imagine, as regards superficial features, typical of the midland alluvial areas of India The level to which water would rise in a boring depends primarily upon its level at the head of supply, now although Sukakheri is 70 feet, and Gadarwara 84 feet, lower than the summit level on the branch railway close to the foot of the hills, the Sitariva river where it enters the alluvium has cut its bed down to about 100 feet below the same level This, of course, acts as a complete drain upon the accumulation of underground water to a considerable depth[1] The only chance then of a spring rising to the surface in such an area would seem to be from a source far up the valley I am not at all prepared to say that the expectation of such a source would be unreasonable, but for the probability that this pressure also would find a leak through bottom coarse deposits to the sides of the valley at the lateral stream channels, and so undergo constant adjustment to the fall The cause of failure here noticed is analogous to that pointed out for the old rock basins at the end of para 8, and it is the effect of the recent erosion described in para 14

20 *Coastal alluvial plains* —The case of alluvial plains ending at the sea is somewhat different from that of the upland valley plains In these latter we can seldom (previous to trial) count upon a greater depth of alluvial strata than the level of the rock bed at the point of discharge, in the former case there is no such limitation, and there would be a general probability of a depth increasing towards the sea margin There would, moreover, be a less chance of great inequalities of depth, for the floor upon which such deposits rest would for the most part have been prepared by marine denudation, which does its work in a more regular manner than atmospheric agencies The prospect then of an artesian boring in a coastal alluvial region would, as regards primary conditions, be reduced to the consideration of the catchment area and rainfall

21 *The Coromandel plains* —The successful artesian borings at Pondicherry give a general illustration of the conditions under consideration, or at least of one phase of them The whole Coromandel coast is fringed with alluvium, although at intervals between the principal rivers rocks come close to the shore, or even touch it at a few points South of the Kistna none of the rivers of the peninsula are able to maintain an encroaching delta, there seems a temporary neutrality established between them and the sea, for on its side the sea does no more than shake out and spread the alluvial matter it receives from the rivers, so that the sea-bottom is almost a simple continuation of the alluvial plain At 10 miles from the shore the depth only varies between 20 and 30 fathoms, giving a slope of 1 in 400, or 15 feet in a mile Under such circumstances the shore line is very regular, almost straight, but inside it the rock margin of the alluvial plain is most sinuous, retreating rapidly inland between the low plateaus of tertiary sandstone that separate the main river basins back to the upland of gneissic rock, and far up the valleys of the principal streams From these highest beginnings of the alluvial area the principal rivers are, or have been till very recently, in the distributing phase of action, *i e* sending off distributaries, or flood water subsidiary channels, any one of which

[1] At a distance of a quarter mile the bed of the Sakar is 95 feet below the level at the Gadarwára boring

may, according to circumstances, be adopted as the main channel, the old one being abandoned. This feature is a necessary condition of a depositing river, for when the stream acts principally as an agent of erosion, it necessarily deepens its channel and fixes its position permanently. Thus it is evident that this plain is of the most recent formation.

22. *The Pondicherry borings.*—Pondicherry is situated on the shore, at the extreme north-east corner of one of these plains, where the alluvium runs up like a wedge between the sea and the rounded south-east edge of the low plateau of tertiary sandstone, which is only 2 miles distant from the town. To the south, for a width of about 15 miles, the plain has a depth (from the shore line) of about 25 miles, with a mean slope of about 5 feet in a mile. To all appearance Pondicherry is thus least favourably placed as regards an under-ground water-supply from the alluvium; but Mons. C. Poulain, the enterprising manager of the Savana factory, undertook the experiment with entire confidence, and was rewarded with success. There are now three artesian wells in continuous operation within a circle of 600 yards radius, close to the sea. The surface at the wells is only from 6 to 9 feet above mean sea level, the extreme tidal range being (for Madras) 5 feet 4 inches. In one case the artesian water rose to a height of 15 feet above sea level:—

Artesian wells at Pondicherry.

Position.	Depth, feet.	Discharge, gallons per minute.	Diameter of tube, inches.	Temperature, Fahr.
I.—Savana	174	30	5·57	91·4
II.—Upâlem	119	100	7·08	..
III.—Jardin d'acclimatation ...	261	146·5	10·23	93·74

Generalised section of well No. III.

Depth.	Thickness.	No.	
Feet.	Feet.		
4	4		Soil.
14	10	1	Clayey sands.
27	13	2	Alternating coarse sands.
36	9	3	Black clay and fine sand.
40	4	4	Clayey sands.
52	12	5	Clean sand.
89	37	6	Black clays, some sandy.
101	12	7	Alternating sand and clay.
110	9	8	Sandy clay and sand.
158	48	9	Black clay.
180	22	10	Fine earthy sand.
198	18	11	Coarse sand, partly ferruginous.
217	19	12	White sand, earthy, and conglomeratic.
235	18	13	Sand and ferruginous grit.
242	7	14	Fine sand.
261	19	15	Sand, gravelly and ferruginous.

Decayed wood was brought up from several of these bands, 2, 5, 13, 14, and 15; and also fragments of shells, presumably marine, from No. 9. There is a decided correspondence in the sections of the three wells, the black clay bands Nos. 6 and 9 being well represented in all, and indicating a steady

access of sea-water at whatever depth. A good instance of how rapidly and effectually this duty is performed may be quoted from Madras: a tide gauge cylinder was sunk to about 12 feet on the shore close to the high-water mark, and it filled with fresh water.[1]

26. *Western India: boring at Ahmedabad.*—In the report of the Committee on the project for the Calcutta boring[2] I find the following mention of an apparently successful artesian boring in an alluvial area of Western India: "While drawing up our report, we hear of the eminent good fortune which has attended Lieutenant Fulljames' attempts in Guzerát, at Ahmedabad,[3] where water rushed up with great force through the tubes to the astonishment of the inexperienced in such matters. The soil in the plains of Guzerát is so sandy and unretentive of moisture that most of the wells have a depth exceeding 100 feet. The boring was commenced at the bottom of an abandoned well." I have not succeeded in finding any further information regarding this boring (see note 3, p. 6), and probably the last sentence of the quotation explains this defect, in that the spring was only partially artesian, and never reached the surface. This is an important resource that is not known of in many districts where it might be of use. I have been told that in parts of North-western India it is the practice to excavate wells down to a certain bed of clay, and to bore a hole in this, through which the water rises to a more or less constant height.

27. *Deltas.*—The familiar word 'delta' is most inconveniently vague as a term of physical geography, being based upon quite a special combination of conditions, the essentials of which commonly occur without producing anything like what is generally understood as a delta. A strict definition of the term would be—the area embraced between the extreme distributaries of a river and the sea. In the case of the Nile the land so defined did form nearly an equi-lateral triangle, and hence the name from the Greek letter Δ. The word always implies proximity to the sea, but the essential point of the feature is the permanent dividing of the waters of the river, and this may occur anywhere in the alluvial area, however far from the sea. To take an extreme instance: there was almost certainly a time (and it might recur but for human interference) when the Jumna divided its waters near the sub-Himalayan zone, sending some to the Arabian Sea and some to the Bay of Bengal, and thus the whole of peninsular India would be included in its delta, as above defined; or again, most of the coastal plains of the Coromandel, as already described, are deltaic, as embraced by the distributaries of the principal rivers; but they have a much greater slope than obtains under the fluvio-marine conditions of the true delta, which may be described as the extreme form of alluvial ground, where deposition from inundation merges into deposition in a water-basin. In the lower parts of a delta all except the topmost layers must be of the latter kind, except where depression has intervened to sink a land surface below the sea level. Even as thus described, deltas vary greatly from the point of view of artesian conditions. Mere size is an important consideration here, involving as it does the greater or less prolongation of the strata with a minimum slope and having a minimum capacity as water-bearing.

28. *The Calcutta boring.*—The foregoing reflections may go far to explain

[1] Information from Captain Baird, R.E., in charge of tidal observations: "I have, I think, given all the important facts of the experience at Pondicherry; for further particulars reference may be made to Records, Geological Survey of India, Vol. XIII, pp. 113 and 191."

[2] Jour., As. Soc., Bengal, 1833, Vol. II, p. 372.

[3] The elevation of Ahmedabad is 195 feet; the distance from the head of the Gulf of Cambay is 50 miles.

the fulure of the artesian boring at Calcutta in 1838,[1] with the inference that in such a case there may be no chance of success Calcutta, although 70 miles from the sea is far within the tidal area of the delta, the nearest edge of the alluvial basin is about 80 miles distant to the west, a large portion of

hnical head of the delta,

is 170 miles to the north

Calcutta the strata are as nearly horizontal as any deposits can be, where, of course, any residue of pressure from the head is of the smallest It may be, too, that in such very fresh deposits still in great part under water, consolidation has been so partial that diffusion of water from the lowest beds can sensibly take effect throughout the mass Some such inferences are, I think, the lesson to be taken from the boring

hopeless The follo

from the account by

Calcutta Journal of Natural History (Vol 1, p 324, 1841)

Section of the Fort William Boring April 1836 *to September* 1838

Depth	Thickness	No	
	Feet		
10	10	1	Artificial soil
50	40	2	Blue adhesive clay, becomes darker from carbonaceous matter till between 30 to 50 feet large pieces of peat were brought up
60	10	3	Calcareous clay, with kankar
75	15	4	Silicious clay green at top lower portion with kankar
120	45	5	Variegated sandy clay, with layers of kankar
125	5	6	Marl
128	3	7	Friable sand, earthy
150	22	8	Marl
175	25	9	Sandy clay with grains of laterite
183	8	10	Quartz gravel finer below
205	22	11	Hard ferruginous clay
208	3	12	Sand more or less indurated
380	172	13	Ferruginous sand with calcareous earthy layers kankar and pebbles of primary rocks are frequent in the lower part, where also fossil bones occurred
382	2	14	Blue marl with shells
392	10	15	Peaty clay, rolled fragments of coal at base
481	89	16	Sand with pebbles of primary rocks, fossil bones, and decayed wood

To all appearance the alternation of beds in this section is very favourable for an artesian effect, and of course upon the withdrawal of stuff from the tube there was a continuous inrush of semi fluid sand from the beds 7, 10 and 16, it was the chief difficulty in the prosecution of the operation, but the water seems never to have risen above the ordinary level of the upper ground water, which varied from 10 to 12 feet from the surface according to the season The frequent occurrence of decayed wood, and especially of bones, down to the lowest beds reached is very remarkable, showing that the deposits there are far from being fully, if at all, marine At the bottom of the bore the pebbles (mentioned in the section) were of

cather ebb to the

lcutta boring but from a drawing to scale of the cylinder let down as a last resource to free the hole by explosion the internal diameter of the tube at the lowest depth must have been at least 6 inches, and it would seem that only one tube was used throughout

large size; it was in the endeavour to break these stones, to admit of the further penetration of the tube, that the tools became inextricably stuck, and the operation brought to an end. The presence of these large stones of primary rocks is the most exceptional fact brought to light by the boring, as compared with what would now be possible in this position. It seems to require the presence of rocks *in situ* much nearer than could have been suspected from the surface features, if, indeed, it do not indicate the local base of the deltaic deposits.

29. *Borings at Venice, for comparison.*—It may be well to give for comparison an instance of successful artesian borings in deltaic ground. Six years after the breakdown of the Calcutta experiment, Mons. Degousée, the eminent French engineer of artesian borings, proposed to substitute artesian wells for the rain-water cisterns upon which Venice had hitherto chiefly depended for its water-supply. Venice is not in the delta of a great river, lying well to the north of the mouths of the Po and the Adige; it stands in the confluent deltas of a number of smaller Alpine streams, but the conditions of formation are the same. From the inner border of the lagoons there is a fringing area of flat alluvial ground, having a minimum width of about 10 miles to the north-west of Venice. Between this and the foot of the mountains there is a zone, 16 to 20 miles wide, of higher ground formed of coarser gravelly deposits, the preglacial 'diluvium' of local geologists, but with undisturbed stratification, and presumably passing indefinitely beneath the alluvium. It absorbs much water from the Alpine streams, and M. Degousée, in his preliminary investigation, looked to these deposits for his water-supply. In this, however, he was mistaken; at least no such rock was struck in the bore; the discharge came from typically deltaic deposits. M. Degousée also recognised the importance of the fact that the fluvio-marine deposits themselves stretched for a great distance beneath the sea at a gentle slope, the 25 fathom line being nearly 50 miles from shore. In several borings a copious discharge took place from a depth of about 200 feet, the hydrostatic level rising to about 9 feet above that of the lagoons. A free escape of inflammable hydrocarbons with sulphurous gas accompanied the water. From these facts, and the proportion of nitrogenous organic matter in the water, it was presumed that the source of the supply was in the marshy ground of the alluvial area; but this may, I think, be doubted; there is abundance of organic matter in the beds themselves for the production of those ingredients, and the rise of water rather suggests that the water stratum is the deltaic prolongation of the gravel deposits of the inner slopes; this may, indeed, have been Mons. Degousée's view of it, only it is not so expressed. In hopes of finding a purer source, one of the borings was continued to a depth of 422 feet, but without any further success. The following is a section of this deeper boring.[1] The upper beds correspond with those found in all the borings:—

Section of Artesian boring: Piazza Santa Maria Formosa, Venice.

Depth.	Thickness.	No.	
Metres.	Metres.		
1·0	1·0	1	Made ground.
4·50	3·50	2	Earthy calcareous sand, marine shells.
4·75	0·25	3	Grey sandy clay.
5 0	0 25	4	Layer of marine shells.
9·0	4·0	5	Clay, blue and yellow.
15·0	6·0	6	Sand, fine, silicio-calcareous.

[1] C. A. de Challaye: *Bull. Soc., Géol. de France,* 2nd Ser., Vol. V. (1847-48), p. 23.

Depth	Thickness	No	
Metres	Metres		
18 50	3 50	7	Sand, bluish, running.
20 30	1·80	8	Clay, grey, marly
21 70	1 40	9	Sand
23 50	1 80	10	Clay
24 30	0 80	11	Sand
25 80	1 20	12	Clay
27 50	2 0	13	Sand
29 20	1 70	14	Clay, peaty
31 0	1 80	15	„ white, firm
31 75	0·75	16	„ peaty, micaceous
33 80	2 05	17	„ marly, firm
45 50	11 70	18	Sand, earthy, compact
46 00	0 50	19	Clay, white, loose
48 0	2 0	20	„ peaty
48 25	0 25	21	„ white
52 50	4 25	22	„ loose, running
53 0	0 50	23	„ white and peaty
53 23	0 23	24	„ white compact
56 50	3 27	25	Sand, earthy, micaceous
57 30	0 80	26	Clay, grey, loose
57 60	0·30	27	„ peaty.
60 0	2 40	28	„ sandy, white, micaceous
76 50	16 50	29	Sand, grey, micaceous, running *Water bed.*
80 0	3 50	30	Clay, white, calcareous, marine shells
80 20	0 20	31	„ peaty
82·90	2·70	32	„ grey, running.
84 85	1 95	33	Sand, grey, very fine
85 0	0·15	34	Peat, dry, light
86 50	1 50	35	Clay, greenish grey
105 50	19 0	36	Sand, coarsish, running, with calcareous gravel and decayed wood
112 90	7 40	37	Clay, grey, light
119 0	6 10	38	Sand, very micaceous, marine shells
125 0	6 0	39	„ very fine
126 50	1 50	40	Clay, bluish, light
126 80	0 30	41	Peat, earthy
130·44	3 64	42	Clay, grey, peaty.
132 12		43	Sand, grey, micaceous

The layers of peat (Nos 14, 20, 34, and 41) are taken to mark four
te acts of subsidence of
1

must now attempt to notice the features of the great Indo-Gangetic plains, though for the special object in view the data of observation are very scanty. In respect of the
with that of the coastal
nble those discussed for
ial plains of the Ganges
occupy a great valley between the rocks of peninsular India on the south and the Himalaya on the north As might be expected, the Himalayan rivers play a completely dominant part in the formation and occupation of these plains The Jumna, which is the most western affluent of the eastern

[1] It may be interesting to mention that five sets of pipes had to be used in this boring of the following dimensions (in metres) —

	I.	II	III	IV	V
Diameter	[illegible]	[illegible]	[illegible]	0·25	[illegible]
Length	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

river-system, leaves the Siwalik hills at a level of 1,100 feet,[1] flows with a westerly curve to Delhi (700 feet), 120 miles to south-by-west of the gorge; here it touches one of the most northerly extensions of the Arvali rocks. From Delhi it flows to south-by-east for 110 miles to Agra (550 feet), where Vindhyan rocks are close by, and thence on to east-south-east for 260 miles to Allahabad (320 feet), where it joins the Ganges. A little above Allahabad the river again touches the southern rocks (Vindhyans), and repeatedly in its due easterly course for 370 miles to below Sáhebganj, where it turns to the south, nearly at right angles, round the north-eastern extremity of the Rájmahál hills (and of the peninsular rock area), into the deltaic region. The elevation here is reduced to about 120 feet. There is a corresponding gradual decrease of elevation eastwards along the upper edge of the plains at the base of the Siwalik (sub-Himalayan) range. At Hardwár, on the Ganges (40 miles east of the Jumna gorge), the height is 950 feet, and at the foot of the Sikkim Himalayas, nearly due north of Sáhebganj, the level of the Teesta at the mouth of its gorge may be about 500 feet. The following table of levels along the Northern Bengal State Railway, which runs in a nearly north and south direction from Siliguri (about 8 miles from the foot of the mountains) to Sara on the left bank of the Ganges near the head of the delta, gives an instructive section of the plains in this position, showing that for a distance of 60 miles to the north the ground is actually lower than on the banks of the great river :—

Height.	Distance.	Place.	
Feet.	Miles.		
422·18	196	Siliguri . .	From here to Jalpaiguri the line runs to south-east.
322·91	183	Shikarpur.	
276·93	173	Jalpaiguri . .	Close to right bank of the Teesta.
257·12	167	Mundolghat .	Ditto.
238·00	159·5	Haldibari.	
214·28	153	Chilahati.	
186·16	143·25	Domer.	
166·80	132·75	Nilphamari.	
145·53	124	Darwani.	
140·21	120·5	Saidpur.	
121·99	111·25	Parbatipur .	33 miles to east, Kaunia on the Teesta is 111·22′
109·13	100	Phulbari.	
102·59	92·75	Birampur.	
79·96	84·75	Hillee.	
73·25	78·5	Panchbibi.	
76·34	72·25	Jaipur.	
64·97	63	Nawabganj.	
47·49	54·5	Chaitangram.	
49·10	51·5	Sultanpur.	
46·04	46·75	Raninagar.	
47·30	38·75	Atrai.	
49·90	32·75	Madhanagar.	
47·56	24	Nattore.	
57·10	16·25	Malanchi.	
53·73	8·75	Gopalpur.	
55·31	1	Sara . . .	1 mile from Ganges: 112 miles below (south-east of) the Sáhebganj bend.

[1] These elevations and many others throughout this paper are taken from the perfectly accurate measurements recorded on the maps of the Survey of India; but there is often some doubt whether the height recorded may not be the top of a house or other point of trigonometrical observation.

31 *The western system* —The western river system is much more simple all the five rivers of the Punjab (the Sutlej, Beas, Ravi, Chinab, and Jhelum), and their great confluent, the Indus, follow a more or less direct course from the hills to the sea The Sutlej is the chief exception to this rule from Rupar, where it leaves the Siwaliks, at an elevation of 875 feet, it flows westwards for about 100 miles to its junction with the Beas, near Sobraon At Ferozepore, 30 miles below this junction, the plains' level is 645 feet at Bahawalpur, 212 miles lower down and 70 miles above the confluence with the Indus, the elevation is 375 feet

32 *The 'Divide'*—The ground between these two river systems is in respect of its drainage the most peculiar portion of the Indo Gangetic plains It cannot be called a watershed, for no rivulet from it runs into either the Jumna or the Sutlej, and, except along the very base of the hills where alluvial accumulations have raised the surface considerably above the level of the great rivers at their gorges,[1] the highest ground on any longitudinal section of the plains is found at the old alluvial banks of the Jumna Thus, on the section at about 20 miles from the base of the hills, passing through Ambala and Saharanpur, the levels on the old Jumna banks are 928 feet and 924 feet, that of the intervening valley being 876, at the banks of the Markanda (the nearest minor river to the west) the level is 913 feet falling off to 905 at Ambala and 871 about Sirhind, at the Hindan (the first stream east of the Jumna) the level is 910 feet, falling off to 900 feet at Saharanpur and 884 at Rurki (Roorkee) The level of the Sutlej at Ludhiana is about the same as that of the Jumna at Karnal, the latter being twice as far from the hills This area between the Jumna and the Sutlej has, in fact, the same configuration as any other parallel segment of the plains It is 75 miles wide between the gorges, but owing to the divergent directions of these two rivers it rapidly widens, on a parallel line through Delhi the Jumna and Sutlej are 230 miles apart Two considerable streams, the Markanda and the Ghaggar, and many minor ones, leave the hills within this area, and flow straight away seawards, but they are nearly expended by ... the south boundary of the province, Bickanir It is easy, however, to imag ... by ... and more obscured by the ever encroaching ... west A line or band of minimum elevation is determined where the alluvial spill from the Arvali axis meets that from the Himalaya The 700 feet contour at Delhi can be followed to the west by north a little south of Rohtak and of Hissar, the surface rising from it both to north and south Between Hissar and Sirsa it bifurcates, going north north west along the Himalayan spill to south of Lahore (709 feet), and curving to the south-west along the Arvali spill to the west of Bickanir (715 feet)

33 *Recent erosion* —The whole of these Indo Gangetic plains are then of very recent alluvial formation But here too we find the same feature as already noticed in the case of the midland alluvial areas the greater part of the plains, and most markedly in the marginal zone, the land is not now subject to inundati... t for themselves permanent ... posits, which are generally expos... the present inundation valley ... f land have become current in the Anglo Indian vernacular *Hadar* for the inundation valley, and *bhangar* for the upland. The word *doab* (two waters) for the

[1] At the Mohan pass midway between the Jumna and the Ganges the top of the diluvial slope has an elevation of 1,400 feet

area between a pair of confluent rivers is also a familiar term in India; it is in a manner the converse of the word delta. Various explanations of this altered condition of the plains may be attempted by means of earth movements; and such causes have presumably operated locally within the period in question; but I am inclined to account for the feature as in the case of the Narbada valley (para. 14), by the general deforesting of the country that has been steadily in progress since prehistoric times, and the great disturbance thereby effected in the regulation of atmospheric waters. The equable universality of the fact is greatly in favour of such an explanation. The obvious effect of this superficial condition in lowering the head of water available for artesian springs has been already mentioned (para. 19), although the direct action of the prime cause in lowering the spring level in the plains seems to have outdone this secondary effect, as will be pointed out in the case of the Jumna.

34. *The water-head zone, eastern area.*—With the partial exception mentioned in the last paragraph the configuration and, as far as can be seen, the construction of those great plains are as favourable as any original basin could be for the success of artesian borings. Leaving out of count, as we may for the present, the comparatively insignificant areas of the southern tributaries, we have a great inclined plain with a gradually increasing slope, up to as much as 50 feet in a mile, next the mountains. This highest and steepest zone, for a width of 10 to 12 miles, is formed of boulders, gravel, and sand of various degrees of coarseness, and may be appropriately described as diluvial as distinguished from the alluvium of more tranquil deposition. It is locally called the *bhábar*, or forest belt; it is naturally very pervious to water, so much so that minor streams, unless when in flood, are wholly absorbed in it. Outside this zone, where the coarser deposits end, and the slope is reduced to about 12 feet in the mile, there is a copious outflow of springs producing a second zone, of specially swampy ground with corresponding vegetation, and well known as the *tarai;* it gradually merges into the more habitable area. It used to be supposed that the tarai occupied an actual depression, until simple levelling showed it to have the very considerable slope of 12 feet in the mile, the marshy condition being fully accounted for by the continuous supply of surface water from the *bhábar*. The latest popular misrepresentation of this phenomenon describes [1] the boulder deposits of the *bhábar* as resting in an actual basin of impervious clay, from the outer rim of which the water absorbed on the upper side is discharged again into the tarai. Such an arrangement would, I need hardly say, put an end to speculation as to artesian wells in the plains. It is, however, presumable that this highest zone of the plains deposits is almost exclusively formed to its very base of like coarser materials; that near the base such deposits extend to a much greater distance than at the present surface; and that they are there in continuous connection with similar beds underlying the plains more or less continuously throughout. No doubt, as the formation grew in thickness the coarse beds became accumulated at the steeper edge of deposition, and at their outer limit were freely interbedded with the finer deposits, so that at any point a bed of clay may be found passing under the upper beds of the *bhábar* gravels; but there can scarcely be a doubt that on the whole the distribution is as I have described it. From this point of view the tarai springs become simply the overflow from the fully charged lower water-bearing strata throughout the formation; and this level may be taken as the minimum "head" from which an artesian spring may be expected at any point in the plains.

[1] The Tarai District: E. T. Atkinson. Government Press, North-Western Provinces, 1877.

35 *Different condition of western area* —Unfortunately this gauge is not available where it is most wanted the tarai does not occur to the west of the Ganges ... ctions of the two ... section for 12 mile ... road, and II, a section in the same position on the Sahâranpur Mussoorie road, the lowest figure in No I being at the outer edge of the tarai and ending at 12 miles from Haldwáni at the foot of the hills, in No II the highest level begins at 12 miles from the foot of the Siwaliks at Mohan both are taken from the level charts of the Survey of India —

I		II		
791		979 65		The exceptional cases showing a rise are probably on bridges or other artificial surface
763	—28	974 79	—4 86	
746	—17	965	—9 79	
724	—22	947 27	—17 73	
712	—12	940 62	—6 65	
701	—11	935 13	—5 49	
680	—21	928 30	—6 83	
682	+2	927 68	—0 62	
678	—4	920 77	—6 91	
677	—1	916 79	—3 98	
662	—15	905	—11 79	
658	—4	912 07	+7 07	
651 87	—6 13	905	—7 07	

The total fall on the tarai section is 139 13 feet and on the parallel section to the west only 79 65 This great contrast of surface conditions seems to be fully accounted for by the relative efficiency of the agents of denudation in the two regions In the eastern river system there is actually and relatively far more water-power at work, and this difference is increased by the ... upon the water in the western area ... protected by vegetation, but the sol ... more developed, so that the amount ... equal areas is much greater The effect seems imperceptible in the open plains for example, the level (408 feet) at Multan, about 300 miles distant from Madhopur at the gorge of the Ravi[1] (the central one of the five Punjab rivers) is the same as that at an equal distance, half-way between Cawnpore and Futtehpur, below Hardwár, at the gorge of the Ganges It is naturally near the hills that the effect is seen, where the surplus burden is left behind, to be affected only by the feeble action of a moderate rainfall and the irregular action of the wind For an excellent description of the conditions under notice reference may be made to Mr B H Baden-Powell's account of the *chos*, or sandy-bedded torrents, from the Siwaliks in the Hoshiárpur district[2] Under such circumstances a tarai is, of course, out of the question

36 *The water-head level in western area* —The distribution of the underground water in these north-western plains is a very obscure question, and a most important one in the present inquiry The few facts I can quote relating to it indicate how variable it i ... nary observation In 1878 I noticed a w ... head of the boulder zone, close to the *rau* (torrent), 8 miles west of Mohan, about midway between the Jumna and the Ganges A considerable depth had already been attained, alto-

[1] The flood level at Madhopur is 1,146 feet, that of the old gravel bank being 1,197 feet (information kindly supplied by Mr H Garbett, Superintending Engineer)

[2] Selections from the Records of the Government of the Punjab, new series, No XV, 1879.

gether in coarse boulder gravel; and I have been informed of the progress up to date through the kindness of Captain Baily, R.E., Conservator of Forests. On the 11th December last the total depth was 197 feet 9 inches with 1 foot 9 inches of water; by the 5th of March the water had increased to 2 feet 8 inches, but fell again rapidly, and by the 12th of May the well was nearly dry. There remained another full month of the driest and hottest weather, but it would seem that the depth of 200 feet may be taken as pretty nearly the permanent water level at this point. The elevation of the surface can be little less that at Mohan (1,400 feet), which is about the greatest elevation of the recent deposits along the whole *Himalayan* border. According to preceding considerations, this level of 1,200 feet would be a maximum limit of the 'head' from which the underground distribution is regulated. We have not far to go for a qualifying observation. An account is given[1] by Lieutenant W. E. Baker (Engineers) of the sinking of a well on the right bank of the Jumna at Ráyanwála, near the base of the Siwaliks. It is 3 miles below Hátníkúnd, where the deposits terminate within the open gorge of the river, but the elevation is still 1,052 feet. The surface is less than 10 feet over the water in the river, and only 60 yards from the edge, but the well was sunk through boulders, gravel, and sand for 60 feet without finding water. Lieutenant Baker mentions the fact as an anomalous instance of the impermeability of the coarse river deposits at this spot, contrasting it with what takes place in the similar deposits of the bhábar east of the Ganges, as already noticed. This is of course an erroneous impression: there is a deep and rapid current in the Jumna at Ráyanwála, and the traction of the stream does not give any particle of the water time to change its course and sink into the ground. The case is very different for small streams spreading out over the surface. Another well was sunk through the very same deposits at Chándpur, only 400 yards from the bank at Ráyanwála, the surface being 14 feet over the water in the river. In this well a permanent water level was found at a depth of 80 feet, 66 feet below the water in the river, or at a reduced level of about 972 feet. These observations are very interesting, as showing that the river valleys have no present effect (at least in the bhábar zone) in draining the deep ground-water from the adjoining uplands, their natural action in this way being outdone by the drain towards the plains. We may then perhaps take this Chándpur well as giving a lowest limit (972 feet) for the head of water from which the deep lying strata to the south may draw their supply. It is presumable that in parallel sections away from the river this level would not be so low, the great facility of drainage in the khádar of the river taking greatest effect on the ground immediately to the north.

37. *Ground-water distribution away from the hills.*—A seemingly analogous case to that of the Chándpur well, but where it might be less expected —in the lowest ground in the plains' section—has been brought to my notice by Captain J. C. Ross, R.E., from observations made during the construction of an 'escape' into the Jumna from the southern branch of the great Ganges canal above Etáwah, 250 miles to south-south-east of Chándpur. The banks of the river here present a most intricate maze of deep narrow ravines worn by the rainwash in the edge of the bhángar, the level of which, at a short distance from the river, is 517 feet. The levels of the surface and of the ground-water given in the following table are taken among these ravines. The flood level of the Jumna here is about 410 feet and its lowest level about 391 feet.

[1] Jour., As. Soc., Bengal, Vol. VI (1837), p. 54.

		Water levels	Level of ground	Intervals	Distance
				Feet	Feet
Jumna river	1	394 54			0
	2	394 21		317	317
	3	394·43		500	817
	4	394 11		500	1,317
	5	393 74		500	1 817
	6	391 63		500	2 317
	7	385 45	410 05	500	2 817
	8	394 31	416 36	2 548	5 365
	9	401 48	430 32	2 073	7,438
	10	422 66	440 49	1,578	9 016

In No 7 of this table we find, at a distance of about 940 yards from the river, a position of lowest water level, more than 9 feet lower than the water in the river, and 25 feet from the surface The steady rise of the water level from this line towards the river shows that this is distinctly a source of percolation, and the more rapid rise towards the upland to the north indicates the much higher area, where, in fact, the permanent feet from the surface, or at a redı the ground water in uplands towards deep river channels is a familiar fact, it is the natural operation of the conditions upon which all drainage works are based There is an excellent illustration of this in a paper by Lieutenant W E Baker (Engineers), on an oblique section of the plains between Karnal on the Jumna and Ludhiana on the Sutlej [1] The figured section shows the depths of the wells along the line, and how markedly that depth increases as the rivers are approached The general understanding of this feature is that below that deep well water level the whole ground is permanently stocked with water in the permeable strata If this were the case the main rivers should give a minimum water level for the whole area and the fact brought to notice by Captain Ross must then represent an actual removal of water at the surface, for which the only assignable cause would be evaporation I am not prepared to say that this is impossible, I have elsewhere[2] made large demands upon the climatal conditions of this part of India, and these conditions must be concentrated among the steep bare surfaces of clay and sand in the ravines of the Jumna, percolation is, moreover, a slow process in such fine deposits The alternative inference would be that below the river bed, and practically isolated hangar area, or in which to establish a percolation slope from the Jumna of nearly 18 feet in the mile The line of lowest ground water (No 7 of the table) would be where this plane of under ground drainage intersected that of the upland water table So far within the basin of the eastern river system there is some difficulty in ely presumable that beneath the Gan- remarks can, however, scarcely affect the question of deep artesian springs, unless as showing that the source of such springs must be cut off from the waterless ground referred to

[1] Jour, As Soc, Bengal Vol IX (18 088

[2] On the *Reh* soils of Upper Ind , Records, G S I (1880) V XIII, I

38. *Desiccated ground south of the Punjab plains: Bickanir wells.*—In the basin of the western river-system there would be no need for hesitation in assuming the deep exhaustion of water from the surface. The following translation of a native description of the wells in Bickanír will give a good idea of the desiccated ground lying to the south of the plains of the Punjab. The area is almost all within the alluvial spill from the Arvali, but the deposits are quite continuous with those of the spill from the north; the change from one to the other can only be detected by a levelling instrument. The account was sent to me by Colonel C. A. McMahon in 1874: it is as follows:—

"Within the city of Bickanir there are 14 wells, the water of eight of which is sweet, and of six brackish. Outside the city there are 24 wells, the water of two of which is slightly brackish, and of the remaining 22 sweet. In the Fort there are four wells, all of which yield sweet water. There are, therefore, in all 42 wells. Each of the wells inside the city is 60 *purs* or 300 *hath* (cubits) deep. The wells outside the city and in the Fort are 50 *purs* or 250 cubits deep. When a well is dug various kinds of earth are found. First gravelly, which is called "*marand*" in this country, to a depth of 5 or 6 cubits; next, *seeah matti* (black earth), varying from 15 to 20 cubits in depth; next, *safaid matti* (calcareous chalky or white earth), from 80 to 100 cubits deep; next, *panjrangi matti* (five-coloured earth), to a depth of 40 to 50 cubits; after that comes *peelee matti* (yellow earth), 70 or 80 cubits deep; next, *sangreza matti amez* (gravel mixed with earth) to a depth of 30 to 40 cubits; and lastly, a kind of soft rock, *zamin doz pathar*, 5 or 6 cubits deep, is reached, after which a spring is arrived at. The cost of sinking a well is from Rs. 30,000 to Rs. 40,000. Most of the wells have two drawing wheels; some have four; and one, known as "Alak Ságar," has eight drawing wheels. This last cost about a lac of rupees, and its water is that generally used by the city people, who obtain the same by paying to the *málees* who draw the well at the following rates: for 1 small pice a *matka* (or large earthen jar), 1 rupee for 12 bullock pakhal[1] or 5 camel pakhalfuls. The wells are all worked day and night, and not withstanding this the water is inexhaustible. In the villages between Bickanir and Sujangarh (75 miles to east-south-east), as well as in those between Bickanir and Nagour (62 miles to south-south-east), and between Bickanir and Jaisalmir (160 miles to west-south-west) wells are 80 *purs* or 400 cubits deep: and between Anupgarh (80 miles to north) and Bickanir they are 200 cubits in depth."

At the same time as this document a specimen was sent from the Political Agent at Bickanir; it had been taken from the bottom of a well that had recently been sunk to a depth of 370 *haths*, and Colonel McMahon states that he was informed that the Bickanir *hath* is equal to about 21 inches. At this scale the well in question would be 647 feet deep; but even taking the cubit to be 18 inches the depth would be 555 feet. It was quite indeterminable whether the "soft rock" from the bottom was a decomposed sandstone or a partially consolidated bed of the alluvial deposits. There is, indeed, no reliable information regarding the geology of Bickanir. In the recently (1879) published official Rájputána Gazetteer (Vol. I, p. 182), it is stated that "the city of Bickanir is built upon a rock formation," and that "it is considerably higher than the surrounding heavy sand tract and is composed of sandstone." On the large scale map of the city of Bickanir, lately issued by the Survey of India, there is clear indication of low flat hilly ground immediately to the south of the city; it is not improbably a small outlier (or inlier, if we regard the alluvium as a formation) of the horizontal Vindhyan rocks. There are numerous heights marked on this map; the highest is 799 feet in this ground, and the lowest is 715 to the north-east of the city. I cannot, however, think that any of the city wells, as described in the foregoing note, are in the old rock. As

[1] A pakhal is a pair of large leather bags or packs for water-carrying laden on animals.

regards the point now under consideration the question is not of importance, as in either case the source of water would be the same

39 *Underground features of the great plains* —It is necessary to say something regarding the underground conditions of the basin In enquiries for artesian water the usual first question is as to the depth, and because in many cases this can be answered with considerable accuracy, a vague answer is received as a mark of imbecility I have explained in para 6 how this is the essential difference between the two classes of artesian sources, and a good illustration of this practical difficulty, supported by trial borings, was given in the case of the Narbada valley (paras 16, 17, 18) In the case of the Indo Gangetic plains this question may be said to present the leading puzzle in Indian geology—to give an account of the relations between the highly contrasting rock features of peninsular and extra-peninsular India all direct observation of the connecting structural features being concealed by the alluvial deposits of the intervening plains A few statements will show how the matter stands All the rocks in contact with the alluvium on the south are of immense antiquity, the small patch of the Gondwana formation at the extreme east in the Rajmahál hills being the newest, and it is of middle secondary age whereas, on the north of the plains, there is a prodigious thickness of newest tertiary deposits Again on the south none but the oldest rocks of all, the transition and metamorphic, have undergone more than local disturbance, while on the north the newest strata exhibit extreme disturbance througho [illegible] the rock surface on [illegible] severally and successiv [illegible] ning that surface, and in this case there can be no doubt as to the very strong and late action of crust movements on one side of the area From the absence in the peninsular area of any trace of that disturbance, or of the rocks upon which it operated, it seems probable that the conditions of that area extend for a considerable distance northwards, and that the plains on the south are underlaid possibly at no very great depth, by gneissic rocks there are inliers of gneiss and granite appearing through the alluvium to the north of the transition rocks in Bahar, and the structure of the Vindhyan basin suggests that its present northern scarp, overlooking the alluvium between the Jumna and the Sone, is not far from its original boundary in this direction and that there also the gneiss is close by This inference has to be qualified by another The great antiquity of the southern area does not refer only to the age of the rocks found there, as already mentioned but also to the actual configuration of that area In the discussion of the Narbada valley case (para 17), it was shown that the gneissic area of Lower Bundelkhand was very much what it is now in the Deccan trap period (upper cretaceous), a bay of a great basin to the north Again, far to the east in the actual river valleys draining to the north from the gneissic upland of Hazaribagh, remnants of Talchir (lowest Gondwana) deposit occur at the level of the Ganges alluvium It is thus pretty clear that a great drainage basin in the approximate position of the Ganges valley has existed since at least pretertiary times, and it is highly probable that the tertiary deposits so enormously developed at the base of the Himalaya extended over a great part of that basin, they may only be overlapped by the present alluvium at a short distance from its south margin In an artesian boring the passage from the alluvium into upper tertiary beds, such as are now exposed along the foot of the mountains,

zone of the sub-Himalayan rocks themselves, and to take up the discussion would lead us into geological depths, of which many will, no doubt, think there has already been too much in what is meant to be a practical essay. The foregoing indications will suffice to show that, however interesting such discussions may be, they are practically futile when we come to such particulars as estimating the depth of the upper deposits at any point. Observation has done its duty in pointing out that the main conditions for successful artesian boring are to all appearances present.

40. *The Ambála boring.*—I may now make some remarks upon the three borings that have been made in search for water in the upper regions of the plains, beginning with the most important, that at Ambála. The following section is somewhat abridged from the detailed record, some of the thinner alternations being grouped into a single band:—

Depth.	Thickness.	No.	Section of artesian boring at Ambála (1st November 1869 to 1st February 1872).
Feet.	Feet.		
4	4	1	Soil.
12	8	2	Sand and sandy clay.
27	15	3	Clay, stiff, with kankar at base.
41	14	4	Sand, fine; damp at 27 feet, water at 32 feet.
50	9	5	Clay, brown and blue.
87	37	6	Sand and clay alternating.
122	35	7	Clay, brown, very stiff.
124	2	8	Kankar (impure segregated limestone).
154	30	9	Sand and clay, with kankar at 151 feet.
166	12	10	Clay, dark red.
174	8	11	Sand with clay; tubes sunk 4 feet by their own weight.
181	7	12	Clay, with kankar at base.
199	18	13	Sand, with some clay and kankar; on reaching this bed water rose suddenly 40 feet, and in two hours 70 feet; its temperature was 78°.
202	3	14	Clay, with kankar.
211	9	15	Sand.
223	12	16	Clay, red and brown, with some sand and kankar.
250	27	17	Sand, with a little clay and kankar.
278	28	18	Clay, top very stiff, red, with 'shingle.'
302	24	19	Sand, with some clay, pebbles, and "boulders."
327	25	20	Clay, with some kankar.
332	5	21	Sand, dark-brown and grey.
335	3	22	Clay, stiff, brown, with kankar.
376	41	23	Sand, with some clay and kankar.
394	18	24	Clay, with some sand.
424	30	25	Sand, some gravel, with "large stones and boulders and black kankar."
431	7	26	Clay, stiff, red.
432	1	27	Sand or silt, dark, running.
446	14	28	Clay, red, very sandy.
448	2	29	Sand or silt, dark, running.
451	3	30	Clay, red, stiff.
459	8	31	Sand, dark, running, with kankar and "clay boulders."
463	4	32	Clay, stiff, red, with kankar.
467	4	33	Sand, fine, running.
477	10	34	Clay, stiff, red.
484	7	35	Sand, running sand.
502	18	36	Clay, some stiff, some sandy.
507	5	37	Sand, running.
515	8	38	Clay, stiff, red.
546	31	39	Sand, coarse.
585	39	40	Clay, stiff, some sandy.

Depth.	Thickness	No	Section of artesian boring at Ambála (1st November 1869 to 1st February 1874)
601	16	41	Sand [illegible]
641	40		
644	3		
678	34		kankar
683	5		
689	6		
701	12		

Ambála is only 20 miles distant from the nearest point of the Siwaliks, and this proximity is the only unfavourable point in the prospect of the boring for being thus on the upper and steeper slope of the plains there is risk of its being above the line of artesian rise, which itself slopes southwards from the presumed head to the lower edge of the deposits Still there is a fair margin for success The level of the Ghaggar, where it cuts the base of the Siwalik hills at Devinagar, 25 miles due north of Ambala, and the proposed site of the reservoir for the Ambála water supply, is 1,118 feet There are no observations as to what may be the permanent level of the underground water in this position, but I have pointed out (para 36) what is presumably a lowest limit for the head level in that ground, namely, the water level (972 feet) below the bed of the Jumna at the point where it leaves the hills, and the surface level at Ambála is 905 feet. Even if the rise of 70 feet that did occur at the depth of 200 feet (see table) were derived from that highest source, there would still be hope, for it is very possible, or even probable, that an absolutely higher rise from the same head should be derived from a lower stratum, as the rise is more influenced by the variations of potential discharge in the several water strata than by the head, the head itself being determined by the total resistances. It would be quite in the natural order for case 6 to occur below case 3 of the experiments described in para 5 There is nothing whatever in the above section of the boring to suggest that the band No 13 is the base of the alluvial deposits, the beds below that level are decidedly of the same type, and the equal frequency of alternations shows that the stratification is still undisturbed. On the whole the section seems promising for ultimate success, the great thickness of clay lower down, in which the bore was stopped, gives security for the isolation of any water stratum in coarser deposits that should be found at the base of the formation [1] In this respect—the prospect of finding such basal deposits—the position of Ambala, near the upper margin of the basin, is favourable The mention of 'boulders' in several beds is misleading I made early enquiries about it, and Major Thackeray, R.E, who was then Executive Engineer in charge of the final operations for extracting the broken tubes, gave the following information (30th March 1874) "I cannot trace any records of larger stones being found than the one I send you (from bed 25), nor of any boulders having been smashed up" From the mention of "clay boulders" in some places I fancy that all were of that nature, lumps of clay partially consolidated, perhaps by lime carbonate The 'large stone' referred to is an oblong pebble of quartzite, little more than 2 inches long and about 2 cubic inches in volume, it is very irregular in shape and but partially water worn, but it has no fresh surface of fracture Mr T. [illegible]

[1] The bottom 41 feet were bored beyond [illegible], [illegible] broken [illegible] at the depth of 600 feet.

Depth	Thickness	No	Sect on of the boring at Bh wani 1877
207	22	6	Clean sand
234	27	7	Sand with imperfect pebbles of sandstone at 231 a large boulder got up (sandstone)
238	4	8	[illegible]
287	49	9	[illegible]
396	109	10	[illegible]
413	17	11	[illegible]
417	4	12	[illegible]
431		13	Sand

The water at the bottom was still brackish The samples described in this section were carefully examined on the spot by Colonel McMahon, a most competent judge, who recorded the following observations —' The 'clay' is simply very fine earthy sand cemented into a mass by the infiltration of carbonate of lime the '*conglomerate*' is coarser sand the grains of which are frequently distinctly waterworn, cemented together in a similar manner, with harder concretions here and there, the 'boulders' are lumps, 4 or 5 inches long, of dark earthy sand, consolidated into concretionary nodules by carbonate of lime, and sufficiently hard to require a smart blow from a hammer to break [illegible] As far as the boring has gone [illegible] bed of uniform material, [illegible] admits the free passage of the rain falling on the surface of the ground [1] The absence of any clay deposit, as well as of any coarser water rolled materials in such comparative proximity to rock masses, throughout so great a thickness of deposits is remarkable, and, of course, very unfavourable for any project of deep-well sinking in this region

42 *The Sabzalkot boring* —There only remains to be noticed the boring at Sabzalkot, in the Dera Ghazi Khan district of the Punjab It is commonly spoken of as artesian, though it was never expected to be more than partially so, as a source to replenish and freshen an already very deep well in which the water was too saline for use The position would seem to preclude any other expectation From the best information I can procure as to the ground, the place is a small fortified outpost close to the frontier, at the foot of a long slope 4 miles from the base of the hills, and 28 miles from the Indus, in a direct line through Asni The alluvial level at the river is 295 feet, stretching nearly to Asni (10 miles), where the height is only 302 feet, the direct distance from the sea is 350 miles From Asni there is a rise of nearly 5 feet in the mile to the frontier road, at 6 miles to westward, where the elevation is 331 feet From this road the ground is said to slope at about 8 feet in the mile up to Sabzalkot, 12 miles which would give an elevation of 427 feet for that place I think it likely that the slope increases very much towards the hills, and that the real elevation of Sabzalkot may be considerably higher than the estimate just given If the height given be correct, we have to account for the remarkable fact of the ground water level being 100 feet lower than the water in the Indus for in the well at Sabzalkot it stands permanently at about 224 feet from the surface It would be additional evidence of the great desiccation the ground has undergone in this region of India and of the insignificant effect of streams in mitigating that inevitable result of the destruction of forest vegetation, although the Indus here annually inundates a broad tract of

[1] From Official Correspondence, dated 5th March 1878

ground. The contribution from the western hills is comparatively small, for the rainfall is deficient and uncertain; but every advantage is taken of it by the coarse marginal deposits forming the slopes at the base of the hills. Mr. Ball has described in this very neighbourhood how a steady current of water wholly disappeared at the outcrop of a bed of conglomerate in these deposits.[1] The following table is abridged from the detailed section furnished by the Department of Public Works. There were 194 feet of $9\frac{3}{4}$-inch tubing, to 410 feet; 114 feet of 7-inch tubing, to 524 feet; and 50 feet of 5-inch tubing, to 574 feet.

Abstract section of Sabzalkot boring: Nov. 1870 to Aug. 1878.

Depth.	Thickness.	No. of bed.	
Feet.	Feet.		
157	157	1 to 14	Sand: some beds earthy, some pebbly.
174	17	15	Limestone boulders.
189	15	16	Clay and sand, very compact.
199	10	17	Loose sand and pebbles.
216	17	18	Hard clay and sand.
240	24	19	Brown running sand. *Bottom of well 230 feet; water level 222 to 224 feet.*
247	7	20	Very stiff clay.
251	4	21	Very coarse sand.
267	16	22	Sand and clay intimately mixed.
275	8	23	Fine running sand.
347	72	24 to 35	Alternations of sand and clay.
351	4	36	Gravel with boulders.
406	55	37 to 54	Alternations of clay, sand, and gravel.
410	4	55	Very coarse gravel and boulders. Water abundant.
500	90	56 to 78	Alternations of clay and sand.
526	26	79	Clay.
574	48	80 to 117	Thin alternations of clay and sand resting on a boulder bed, with abundant water.

The comparative scarcity of coarse materials in a deep section so near the hills is fully accounted for by the unconsolidated condition of the newer tertiary rocks forming those hills. The only hard rock mentioned is the limestone of the 'boulders'; it is no doubt the nummulitic limestone from the higher inner ranges. From several of the porous strata passed through water rose freely, but always stopped at the original water surface of the well. The supply from the bottom boulder bed, at 574 feet, is described as 'plentiful'; at the same time, when drawn upon at the moderate rate of 156 gallons per hour, it was lowered 66 feet. This supply is, however, sufficient for the wants of the outpost. The constancy of the level, to which the water rises from so many different strata, indicates a common source, which also accounts for the water in all being brackish, only less so below than in the top beds, and in a drinkable degree to the people of the country who are extensively used to this quality. The origin of this impurity is a point of much interest; there is no known deposit of salt in the rocks forming the adjoining hills; and the conditions generally suggest that its origin may be the same as that of the saline upper *ground-water* so general on this side of India—from the soakage of the early rainfall into the parched ground taking with it the soluble results of earth decomposition at

[1] Records, G. S. I., Vol. VII, p. 147.

THE CALCUTTA BORING.

[*Reprinted from Journal of the Asiatic Society of Bengal, 1833, Vol. II, p. 369.*]

Extract from Report of the Committee appointed on the 27th March 1833, to consider on the expediency of recommending to the Government the continuance of the Boring Experiment.

The principal experiments on record, connected with the operation of boring for water in Calcutta, are those conducted under Colonel Garstin, Chief Engineer, from 1805 to 1820, and those recently made under the superintendence of Dr. Strong, Mr. J. Kyd, and Mr. D. Ross, in 1829 to 1833. The following is a list of their localities and of the depths respectively attained :—[1]

No.	Date.	Superintendent.	Place.	Depth.	Cause of failure.
1.	Dec. 1804	Col. Garstin.	Well near Powder Magazine.	75 ft.	......
2.	Aug. 1805	Ditto.	S. W. of Artillery Barrack ...	119 „	Auger broke.
3.	Sept. „	Ditto.	S. E. of Regtl. Parade ...	55 „	Ditto.
4.	Oct. „	Ditto.	S. E. of European Barrack ...	59 „	Ditto.
5.	Nov. „	Ditto.	S. W. of Artillery Parade ...	80 „	Ditto.
6.	Dec. „	Ditto.	Ditto Ditto ...	127 „	Ditto.
7.	Feb. 1806.	Ditto.	Ditto Ditto ...	94 „	Ditto.
8.	Mar. „	Ditto.	Ditto Ditto ...	124 „	Earth fell in.
9.	Apl. „	Ditto.	Same operation resumed ...	127 „	Auger broke.
10.	May 1814	Ditto.	S. E. of Artillery Parade ...	140 „	Suspended by rains.
11.	Nov. „	Ditto.	The same renewed ...	136 „	Auger broke.
12.	May 1819	Ditto.	On Artillery Parade ...	130 „	Ditto.
13.	Apl. 1820	Ditto.	Ditto.	122⅓ „	Ditto.
14.	May „	Ditto.	Near triangular barrack ...	128 „	Earth fell in.
15.	1815.	Mr. Jones.	Found a spring in red sand at...	70 „	
16.	1826-8.	Dr. Strong.	Bored in the circular canal to...	70 „	Water rose.
17.			He also made several borings in the Salt-water Lake to	40 „	Through similar strata.
18.		Ditto.	Near the Circular Road ...	70 „	Hard kankar.
19.		Ditto.	At Rasapugla ...	70 „	Sand fell in.
20.	1830.	Strong, Ross, and Kyd.	Near the Fort Church ...	176 „	Shaft injured.
21.	1832.	Dr. Strong.	Near St. George's Gate ...	164 „	Sand fell in.
22.	1833.	Strong, Ross, and Kyd.		170 „	Auger broke.
23.	1832.	Dr. Strong.	Under the Lock Gates, Chitpore	70 „	Water sprang up.

The *geological* question of the probability of finding a spring is by no means solved by the results of these numerous experiments. The knowledge which they afford us of the nature of the Calcutta alluvium may be summed up in very few words.

[1] *Vide* Gleanings, i., 114 or 167; iii., 124, 422, &c.; also As. Res., 1814.

After penetrating through the artificial soil of the surface, a light blue or grey-coloured sandy clay occurs, becoming gradually darker, as we descend, from impregnation with decayed vegetable matter, until it passes into a stratum of black peat, about 2 feet in thickness, at a depth, in Fort William, of 50 feet below the surface In excavating the Circular Canal, the same stratum of peat occurred at from 25 to 30 feet, and in the Entally Canal, it lay just below the bed, or 9 feet below the average level of the Salt-water Lake

This peat stratum has all the appearance of having been formed by the debris of *Sundarban* vegetation, once on the surface of the delta, but gradually lowered by the compression of the sandy strata below Assuming that the Salt-water Lake is 5 feet above the average height of the ocean, the peat stratum is about as much more below the present level of the sea

In the *grey or* black clay above, and immediately below, the peat, logs and branches of a red[1] and of a yellow wood[2] are found imbedded, in a more or less decayed state In only one instance have bones been met with (at 28 feet), and they appear from the report of the workmen to belong to deer, though they were unfortunately lost before examination A stratum of sand occurs generally above the peat clay at from 15 to 30 feet deep, from which the wells in the town are chiefly supplied with brackish water

Under the blue clays at from 50 to 70 feet deep, the nodular limestone concretions, known by the name of *kankar*, occur, sometimes in small grains (called *bajri* in Upper India), with the appearance of small land shells, sometimes in thin strata of great hardness, and sometimes in the usual nodular shape

At 70 feet occurs a second seam of loose reddish sand, which yields water plentifully It was reached also in the perforation under the lock gates at Chitpore, and there (as Mr Jones had previously asserted from his own experiment across the river), the supply was proved to be derived direct from the river

From 75 to 125 feet beds of yellow clay predominate, frequently stiff and pure, like potter's clay, but generally mixed with sand and mica Horizontal seams of kankar also run through it, resembling exactly those of Midnapur or of the Gangetic bason

Below 128 feet a more sandy yellow clay prevails, which gradually changes to a grey loose sand, extending to the lowest depth yet penetrated, and becoming coarser in quality until, at 170—176 feet, it may rather be termed a quartzy gravel, containing angular fragments of quartz and felspar larger than peas, such as are met with near the foot of a granitic range of hills

This stratum has hitherto arrested the progress of the auger, the greatest depth attained by Dr Strong near St Peter's Church being 176 feet

The evidence of this gravel might tend to prove that the auger had here penetrated through the bed of alluvium of the Gangetic delta, while the sandy texture of the undermost layers might be compared to the probable condition of the deposits under the now advanced head of

[1] The common *Sundri* of the Sundarbans
[2] The root of some climbing tree, resembling the Briedelia N WALLICH

every respect superior Two chains attached to the ring of a brace head passed subsequently through a triple block fixed to the apex of the gin, and were then led to two powerful crabs, firmly bolted to large fixed sleepers, at about 15 or 18 feet from the gin A chain was attached to each crab, and on the screw of the upper rod being entered into the brace-head, the crabs were worked simultaneously, and the power of both thus brought to bear in raising the mass of the rods, or in any other necessary manner

On the 28th of April the actual excavation of the bore was commenced with a six inch auger, being that adapted to the tubing it was intended to employ. On the depth of 120 feet being attained, the quicksand, which had rendered the first attempt abortive, was again met with. The experience of its previous effects had rendered apparent the necessity of securing firmly the joints of the tubes, which was accordingly done by means of four short but strong screws To this precaution the success of the work so far was undoubtedly to be attributed, as the difficulties were found most serious from the loose, even semifluid, consistence of the sand, which on the removal of a portion of the water, then standing in the tubes within 15 feet of the surface, immediately rose to 17 feet, and, though the work was continued night and day, actually rose faster than its removal could be effected, so that at the end of eleven days and nights of incessant toil it had risen from 124 to 103 feet

Hence it became evident that the only mode of overcoming the obstacles presented by the sand was to force the tubes down till, coming in contact with some firm stratum, the sand should be excluded, by unrelaxing perseverance and much labour, frequently with an advance of not more than a few inches in the day, the tubes at length attained a depth of 157 feet The sand was then perceptibly gained upon, and at 159 feet a stiff clay was reached, and the borer, which during the prevalence of the sand was always behind the tubing, now passed it, and in twenty-four hours attained a depth of 175 feet

The open auger, it was found, could not be used with effect except in working through clay, a valved instrument, therefore, called the "mudshell," had hitherto been employed for raising the sand This tool, however, here became useless from some defect in the action of the valve, which failed either to admit or retain the sand, now coarse and gravelly, and in consequence it was found impracticable to penetrate with it beyond 175 feet One of the augers, however, being fitted with a valve, and otherwise altered so as to retain the sand, was employed with partial success, but not to an extent sufficient to prevent the sand rising in the tubes, since, after working twenty-one days, and the tubing having been forced down to a depth of 177 feet 2 inches, it was found impossible to work the auger lower than 167 feet 10 inches, occasionally a partial advance was made, but it was neither permanent nor certain, from the constant variation of the height of the sand in the tubes

On entering the stratum of stiff clay, above alluded to, the night-work had ceased, but it was again found necessary to resume it as the only means of overcoming the existing difficulties The effect of this was to carry the bore successfully to a depth of 182 feet 8 inches by the 27th of July, when a temporary suspension of the operations took place, from the supply of rods having become exhausted It may be mentioned that

for some days prior to this date considerable inconvenience had been experienced by the stoppage of the borer, both in its ascent and descent, by some obstacle, the nature of which could not be ascertained. Had it been constant in its position, it might have been anticipated that the tubing had again been dislocated or forced from the perpendicular, but so far from this being the case, the borer occasionally descended and was brought up without the least difficulty; this temporary intermission was followed by the re-appearance of the impediment; again it intermitted, and latterly disappeared altogether.

A further supply of the rods having been obtained from Delhi, the boring was resumed on the 13th October 1836. During this interval of suspension, however, it was found that the tubes had sunk by their own weight from 183 to 187 feet, and the bore could now be worked to the depth of 189 feet. By the 10th November following, a depth of 238 feet 5 inches had been attained, the chief difficulty in prosecuting the work arising from the imperfect action of the instrument employed in raising the sand, in consequence of which the whole contents of the shell were frequently removed during its passage to the surface. To the construction of the valves of such instruments much attention ought therefore to be paid, as on the effective action of these the progress of the operations is most essentially dependent.

On the 15th November, an attempt was made to bring up some water from the bottom of the bore by lowering a bottle with a large brass plummet attached to it, to cause it to sink; but unfortunately before it could be raised the connecting string broke, and the plummet was left below. Considerable anxiety was excited by this, from the anticipation (subsequently realized) of the auger coming in contact with the plummet and being jammed within the tubing. On arriving at the depth of 271 feet, the lower part of the mudshell, including the valve, from some unknown cause broke off, and remained at the bottom of the bore. This accident caused much trouble, but after various attempts to extricate the fractured shell the perforation of an aperture in it, by the use of a jumper, admitted of a strong conical worm auger being screwed into it, and by the hold thus obtained it was successfully raised to the surface.

At the depth of 324 feet the borer came in contact with the long lost plummet, and became so firmly jammed between it and the tubing as to foil every effort made for its extrication, though the force applied at one time was so great as to raise the whole body of the tubing about 4 inches, the weight of this being certainly not less than 7½ tons, exclusive of friction. To guard against the inconvenience of an accidental fracture of the rods at any considerable distance beneath the surface, while they were subject to such strains, Captain Thomson of the Engineers suggested that the uppermost rod should be made *thinner* and *weaker* than those within the bore (so as to give way first), but yet capable of bearing a strain of 25 tons. The force subsequently applied caused the rods, however, to break at their connection with the mudshell, and though they were all brought up the tool remained below. A new operation therefore became necessary for extracting the shell, and first the upper portion of it was considerably widened by the use of a jumper. A drill was then introduced, and after several days' labour a hole, sufficiently large to admit of the conical worm auger being screwed into the shell, was drilled. The entire

shell was immediately brought up, bearing ample indications of having been in contact with the plummet, but leaving it still at the bottom of the bore

On the 1st of October 1837 the depth attained by the tubing was 431 feet, while the depth of the bore varied from 418 to 426 feet, according to the height of the sand The water stood from 10 to 12 feet from the surface, according to the seasons By the 30th of April 1838 the bore was 460 feet deep, and by the 18th September following a total depth of 481 feet was reached Just prior, however, to that depth being attained, the progress of the tubing was arrested by large stones requiring the use of the jumper By its aid the tubing was again set free, but at 481 feet again arrested, and a repetition of the employment of the jumper became necessary As the tool originally employed proved insufficient to fracture the stones then met with, a larger and heavier one was attached to the rods, and after a few blows seemed to have effected its purpose, but on attempting to raise it again it was found to be so fi

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of 15 feet, were then given to the head of the rods, in the hope that the vibration thus communicated to them would tend to loosen the jumper from its hold The large accumulation of sand over the tool and round the rods rendered it, however, problematical if the vibrations ever reached the jumper, and if they did, there can be little doubt that the above cause tended most materially to diminish their intensity, as no useful result followed the trial of this experiment Again, and as a final effort, the tubing was securely held down, and four powerful jack screws were applied to raise the rods, which, after stretching 2 feet 6 inches and thereby affording a gleam of hope that the difficulty was vanquished, unfortunately broke off at one of the connecting joints, 160 feet from the surface, the remaining 320 feet attached to the jumper being left within the bore

Under these circumstances the only hope of being able to continue the operations lay in the practicability of unscrewing and raising the rods, and this after much difficulty was at length so far satisfactorily effected by the use of an ingenious instrument designed by Captain John Thomson, that 290 of the 320 feet of the rods were successfully extracted This instrument consisted of three steel arms rivetted to an iron bell, and subsequently welded to the end of the undermost boring rod The interior surfaces of the steel arms were cut in grooves so inclined that on the head of the rod to be extracted being grasped within them, and rotatory motion communicated to the instrument from above, the teeth cut into the soft iron, and by the hold thus obtained the unscrewing and raising were effected The bell acted as a guide, and was made of diameter just sufficient to admit of the instrument being readily worked within the tubing It became necessary to pass iron pins through all the connecting joints of the rods, otherwise the rotatory motion would have unscrewed them.

On the 16th of February 1839 the instrument above described was again successfully employed in unscrewing 20 feet more of the frac-

octagon, acute ridges, about $\frac{1}{4}$ of an inch in height, alternating with the flattened sides The pressure had ruptured the tin at the edge of the top of the case, and the sand was saturated with the water A double case was then constructed, having interior cross pieces to strengthen it, but a similar result to the preceding followed the lowering of this, and for it also the pressure (upwards of 5,000 lbs) was found too great A cylinder of wrought iron was then prepared, and on sending it down the bore it was found so far capable of resisting the pressure of the water as to retain its shape, but the sand was still damped Since, however, the water had only partially wetted the sand, it seemed probable that additional care in soldering and in applying the water proof covering might exclude it altogether, and accordingly it was determined to make the first attempt with this wrought iron case

The depth of water being about 465 feet, the galvanic battery was of course the only igniting agent which could be employed, and the following are the details of the arrangements adopted A wooden plug was turned somewhat larger at one extremity than the collar of the cylinder into which it was subsequently to be driven On opposite sides of this plug grooves were prepared for the reception of the interior conducting wires Considerable difficulty was experienced in making the grooves perfectly impervious to water under great pressure in consequence of the wires being twisted, but ultimately the following means were employed with entire success The grooves were first filled with fine Europe sealing wax, and the wires, being previously made very hot, were forced into and completely imbedded themselves in it Subsequently a red hot iron was held near the wax of each groove till it boiled freely, and a strip of wood was then forced in over the wire so as effectually to close every aperture The interior extremities of the wires were as usual connected by a short piece of thin platinum, in contact with which a cartridge of dry fine powder was placed The main conducting wires were one sixth of an inch in diameter, and their entire length was nearly 1,003 feet As the bore was lined to the bottom with iron tubing, it appeared essential to insulate the conductors as perfectly as possible, and each wire was accordingly first cased in hempen strands, over which a thick coating of pitch and grease was applied, and then the two wires were lashed together by similar strands, and again covered with pitch and tallow A single rope, about 1 inch in diameter, was thus formed, and on immersing the whole in water its action was tested, and a battery of twelve indifferent plates sufficed to effect the ignition of powder

On the charge being placed in the cylinder, and the platinum wire protected by means of a small tin priming tube, the plug was driven into the collar Over it, and for the purpose of preventing the water forcing its \ … , for the conducting … and soldered In … mmunication betwee … galvanic fluid to th… he wires was made considerably larger than that of the wires themselves, and the top of the plug covered with sealing wax The application of a red-hot iron melted the sealing-wax, and on the cap being driven down it rose through the apertures and formed an insulating collar round each

wire. These arrangements being complete, and the battery of 24 cells, 14 inches × 14 inches, in action, the main conductors were connected to those of the cylinder, and the insulating covering continued over the junction, when the cylinder was lowered to the bottom of the bore. On its reaching this the circuit was completed, but no explosion followed; and on examination it was found that from the smallness of the priming tube the platinum wire had come in contact with the metal, by which of course its ignition was prevented. It was also found that though the priming powder was dry, the water had reached the main charge, and completely spoiled it. Further precautions being taken, several attempts were made, but all with the same result; and it became evident that the wrought-iron case could not be rendered water-tight. Recourse was then had to casting a cylinder of iron, half an inch thick throughout, and on trial this was found to be perfectly capable of resisting the pressure of the water, and preserving the charge dry. The first attempt with this failed from some unascertained cause, and as it was thought possible that some portion of the conductor might have come in contact with the iron tubing, an additional covering of lashings, with pitch and grease, was applied for a second attempt. This also failed, and unfortunately in raising the cylinder, to endeavour to discover the cause of failure, the lifting rope gave way and it became necessary to haul on the conductor. This had been done once or twice before without any bad effects, but on this occasion the junction of the wires at the collar of the cylinder was not sufficiently strong to bear the weight, and the case, after being raised for some distance dropped back to the bottom of the bore. All hopes of benefit from this expedient being thus summarily disappointed, it only remains to be stated that the operations of the Committee were finally closed on the 20th of April 1840.

Throughout the course of the preceding narrative, all reference to the geological information the labours of the Committee have been instrumental in eliciting has been avoided, from a desire to render the mechanical details as continuous as possible, but as few such opportunities as the present have ever been given for observing the structure of alluvial Deltas, a condensed summary of the various points of interest to the geologist is now appended.

After penetrating through the surface soil to a depth of about 10 feet, a stratum of stiff blue clay, 15 feet in thickness, was met with. Underlaying this was a light-coloured sandy clay, which became gradually darker in colour from the admixture of vegetable matter, till it passed into a bed of peat, at a distance of about 30 feet from the surface. Beds of clay and variegated sand, intermixed with kunkur, mica, and small pebbles, alternated to a depth of 120 feet, when the sand became loose, and almost semifluid in its texture. At 152 feet the quicksand became darker in colour and coarser in grain, intermixed with red water-worn nodules of hydrated oxide of iron, resembling to a certain extent the laterite of South India. At 159 feet a stiff clay with yellow veins occurred, altering at 163 feet remarkably in colour and substance, and becoming dark, friable, and apparently containing much vegetable and ferruginous matter. A fine sand succeeded at 170 feet, and this gradually became coarser and mixed with fragments of quartz and felspar to a depth of 180 feet. At 196 feet clay impregnated with

iron was passed through, and at 221 feet sand recurred, containing fragments of lime stone with nodules of kunkur and pieces of quartz and felspar, the same stratum continued to 340 feet, and at 350 feet a fossil bone, conjectured to be the humerus of a dog, was extracted At 360 feet a piece of supposed tortoise shell was found, and subsequently several pieces of the same substance were obtained At 372 feet another fossil bone was discovered, but it could not be identified from its being torn and broken by the borer At 392 feet a few pieces of fine coal, such as are found in the beds of mountain streams, with some fragments of decayed wood, were picked out of the sand, and at 400 feet a piece of limestone was brought up From 400 to 481 feet fine sand, like that of a sea shore, intermixed largely with shingle, composed of fragments of primary rocks, quartz, felspar, mica, slate, limestone prevailed, and in this stratum the bore has been terminated.

In conclusion the Committee have much pleasure in acknowledging the valuable aid derived by them on many occasions of difficulty from the advice and ingenuity of Captain J Thomson of Engineers, and they desire also to express their entire approval of the zeal and intelligence uniformly displayed by Sergeant Thomas Longhurst, of the Sappers and Miners, during the whole time he was in charge of the details of the boring operations

Fort William,
Chief Engineer's Office,
15*th May* 1840

D McLeod, *Col and Presdt*
A Irvine, *Major.*
F P Strong
W R Fitzgerald

P.S—Since the above Report has been signed by the Members I have recollected a most unintentional omission for which I am entirely responsible, and which I am therefore desirous of supplying

It is due to Lieutenant Richard Baird Smith of Engineers to state that he has not only taken a great interest in all our proceedings, but has rendered great assistance in carrying them on during the most difficult period of the operation, since he has resided in Fort William, moreover, the employment of the galvanic battery to blow up the lower portion of the tubing, &c., was suggested to the Committee by him, and the apparatus applied in that process, as above described, was entirely on his design I may add that his intelligence and knowledge of the subject enabled him to give essential aid in arranging the materials for the above Report.

D McLeod, *Colonel,*
Chief Engineer.

ARTESIAN BORING AT AMBALA.

[Reprinted from "Professional Papers on Indian Engineering," 2nd Series Vol. III, Roorkee, 1874.]

Report by MAJOR E. T. THACKERAY, R.E., Executive Engineer, Ambala Division, Military Works.

Report on Boring Operations.

In consequence of the scarcity of the supply of water from the wells in the cantonments and city of Ambála, it was determined by the Government in 1869 that the experiment should be tried of sinking an Artesian boring in the cantonments.

Opinions in favor of finding water at a depth of from 200 to 500 feet had been expressed[1] by Dr. Oldham, Superintendent of the Geological Survey of India, to the Government of India, and the experiment was also advocated by H. B. Medlicott, Esq., Officiating Superintendent of the Geological Survey in India.

The engine and well-boring machinery were ordered from Messrs. Mather and Platts, of Manchester. The distinctive features of the machinery are the mode of giving the percussive action to the boring tool, and the construction of the tool or boring head, and of the shell-pump for cleaning out the hole after the action of the boring head. These are described at length with illustrations, p. 106 *et seq.*, in the extra number of the "Professional Papers of Indian Engineering," 1st series, April 1870.

The soil at the bottom of the bore is loosened by repeatedly letting fall (from a height of about 2 feet) cutting tools suspended at the end of a flat rope. After a certain depth has been loosened in this way, the cutting tools are brought up and water is put down the bore (if necessary), and the material, of whatever description, is brought up in a suction pump, about 4 feet long, let down by the same flat rope. The pump is called a slush pump.

In a firm soil a hole could be bored in this way (if sufficient water was available) to a great depth without tubing.

In Ambála the soil hitherto met has consisted of alternate layers of clay and sand at close intervals, and all the sand strata are more or less water-bearing.

In boring here generally the sand-beds have been shut out as soon as they have been bored through, by pressing the tube into the top of the underlying clay strata, and the tubing has generally been kept going, while the boring and pumping are going on, so that the bottom of the tube and the bottom of the hole have been kept nearly on the same level.

But in boring through clay strata the boring tools have been allowed to be some depth below the bottom of the tube.

By this arrangement the hole bored is somewhat larger than the external diameter of the tube (owing to free play of the tools below). This

[1] *Vide* page 46 *et seq.*

is of the greatest advantage in stiff clay soils, because the resistance in getting down the tubing becomes so much reduced

The tubing is pressed down by means of screw jacks adjusted to "clams" firmly fixed to it, occasionally assisted by gentle tapping on a wooden block fitted to the top of the tubing

These screw jacks work against seams let into the sides of an ordinary masonry well, about 30 feet deep, within which the boring was commenced

The machine was erected, and the boring operations commenced on the 1st November 1869, by Mr Herrop, the Engineer in charge of the work, and the boring was continued daily, Sundays excepted, until the 16th April 1870

When the bore had reached less than half its final depth, water was found, and rose in the tube to a level of 35 feet below the surface of the ground The supply was, however, very scanty and could be pumped out in a few hours

In the hope of reaching a more useful water bed at a greater depth, it was resolved to push on and go lower

On the 16th April 1870 a depth of 381 feet was reached, and it was found necessary to discontinue boring with tubes of 9¾ inches in diameter, a pressure of 64 tons on the screw-jacks being insufficient to force the tubes to a further depth

The 7 inch tubes were then lowered and forced down to a depth of 455 feet, but on the 13th August 1870 the lower tubes broke at the bottom joint 9 feet from the bottom of the bore, a pressure of 80 tons having been exerted on the screw jacks

Work was then stopped, and Mr Herrop proceeded to Sabzalkot under orders of Government, where he was successfully employed in sinking an artesian well

The Ambala boring was not re commenced until the 23rd May 1871, and in that month a detachment of Sappers, consisting of a naik and five sepoys, arrived from Roorkee for the purpose of being employed on the boring

The 5 inch tubes were now lowered and forced down inside the 7 inch tubes to a depth of 552 feet At this depth it was found that the tubes had become bent, and it was necessary to bring up the whole of the 5-inch tubes This was completed on the 22nd July 1871

On again lowering the 5 inch tubes, it was found that the lowest of the 7-inch tubes had become detached from the others, and was obstructing the hole at a depth of 456 feet

Efforts were made to straighten the tube with a large cigar shaped iron bar, but this was not successful

The 5 inch tubes were then again brought up, and attempts made to cut up the broken 7-inch tube In doing this the 7 inch broken pipe was driven into the sand and clay, and the whole of the 7-inch tubes were forced down after it

On again lowering the 5 inch tubes on the 26th August 1871, it was found that the broken 7 inch tube still obstructed the boring

On the 2nd September 1871 the broken tube was cut up by means of a heavy bar, and several pieces of the broken tubes were brought up, and on the 9th September the obstacle was sufficiently got out of the way to allow of the further descent of the 5 inch tubes

During the week ending 22nd September 187[illegible] the [illegible] broke [illegible], and there was considerable difficulty in bringing up the pump which had become covered up in the sand and clay. The pipe was brought up in six pieces, the last portion with the [illegible] being brought up on the 23rd September.

The pipe being now so much damaged as to be unfit for use, operations were now resumed with boring rods.

At a depth of [illegible] feet it was found impossible to pass the pump down the 7-inch tubes, owing to their having become bent from the pressure. A small pump of [illegible] inches diameter was then attached to four 3-inch pipes, and the whole lowered down within the 7-inch tubes; but the pump and 3-inch pipes stuck fast in the joint of the 7-inch pipes. The pump was however extricated on the [illegible] September, and it was then determined, as a last resource, to lower the 5-inch pipes.

Boring was continued by means of boring rods and the 5-inch tubes, and a depth of [illegible] feet was reached on the [illegible] December 187[illegible], when the new [illegible] 5-inch pipe arrived from Calcutta.

The boring then proceeded more rapidly to a depth of [illegible] feet, when the twenty-fourth 5-inch tube from the top of the well broke at the flange under a pressure of [illegible] tons.

The upper 14-inch tubes were then brought up, but the boring was obstructed at the point of fracture, and Mr. [illegible] commenced drilling through the obstruction.

The first obstruction was drilled through, but another was found at a depth of [illegible] feet.

This was also passed, and a third obstruction met with at [illegible] feet.

These obstructions were probably caused by portions of the fractured tube having fallen down the hole.

Another obstruction was met with at a depth of [illegible] feet, but this was got through, and the 5-inch tubes were lowered to a depth of [illegible] feet.

Boring was continued to a further depth of [illegible] feet without tubing, but the sides then began to fall in, and it was necessary to discontinue work.

Several of the 5-inch and 7-inch tubes have been brought up in accordance with the instructions received from Government, but the boring rods, to which the implements necessary to bring up the pipes have to be attached, are only [illegible] inch in thickness, and in consequence have broken, and remain in the hole.

It will be necessary to procure a length of [illegible] feet of rods of not less than [illegible] inches in thickness before the remaining pipes can be brought up.

Specimens of the clay met with at depths of [illegible], [illegible], and [illegible] feet were forwarded to the Geological Survey Office, Calcutta, for analysis, and the results are as follows:—

	No. 1. Depth [illegible] ft.	No. 2. Depth [illegible] ft.	No. 3. Depth [illegible] ft.
Water and organic matter	[illegible]	[illegible]	[illegible]
Insoluble sand and clay	[illegible]	[illegible]	[illegible]
Oxides of iron and alumina	[illegible]	[illegible]	[illegible]
Lime carbonate ...	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]

The specimens, as will be seen from the analysis, contained very little organic matter, and are very silicious, the residue insoluble, in acids, being almost entirely silica

It is worthy of remark that at the depths of 600 to 700 feet, very little sand was met with, a stratum of 5 feet of coarse-grained sand only being found at a depth of 683 feet

Should it again be proposed by Government to sink another boring, the experience gained would seem to show that a larger machine should be employed, and that the diameter of the upper tubes should not be less than 2 feet. It might then be possible to bore to a depth of 1,400 or 1,500 feet.

Nature of soil met with in boring the Artesian well at Ambála.

		Feet		
Clay	Total depth of	$283\frac{11}{12}$	Number of separate strata	47
Sand	do	$106\frac{7}{12}$	" "	39
Sand and clay	do	$54\frac{1}{2}$	" "	12
Kunkur bearing	do	93	" "	22
Boulder do	do	83	" "	16
	Total ..	701		136

Method of withdrawing the tubes.

The pipes used in the artesian well boring were of four sizes, *viz.*, $9\frac{3}{4}$ inch, 7 inch, 5 inch, and 3 inch diameter, and were each 9 feet in length.

The pipes of the same diameter were screwed on to one another by screws and flanges, and were sunk into the boring by means of a Mather and Platts' steam artesian well-boring engine.

The diameter of the boring at the top was $9\frac{3}{4}$ inches, and owing to various obstructions—in most instances caused by bending or fracture of the tubes—pipes of a less diameter than those with which the boring was commenced had to be used. These were lowered inside the larger tubes, so that the diameters of the tubes were gradually contracted, at first owing to an obstruction at a depth of 381 feet being reduced to 7 inches, then at a depth of 456 feet to 5 inches; and lastly, at a depth of 525 feet to 3 inches.

In consequence of the bending and fracture of the 3-inch pipes at a depth of 513 feet from the surface of the ground, it was found impossible to sink pipes of so small diameter to a greater depth than 655 feet, and although the boring was continued with rods and boring tools to a further depth of 46 feet, making a total depth of 701 feet from the surface, the clay at that depth not being supported by tubes began to fall in, and the boring had to be abandoned.

The following is a short description of the means adopted for raising the tubes from the boring :—

An implement called a fish-head, with steel cutters, was attached by a screw to iron rods, which were lowered to a depth of 513 feet, at which depth the 3-inch tubes were fractured. The iron rods—which were also used during the boring work as boring rods—were each $\frac{7}{8}$th of an inch square, and screwed on to one another by means of nuts and screws 3 inches long. The upper end of the rods was attached by clamps to four

screw-jacks, two above and two below; the screw-jacks were turned by eight men, two men to each jack, and on pressure being applied upwards, the steel cutters, which turn on a pivot in the centre of the fish-head, which is attached to the lower end of the rods, open outwards on encountering the jagged iron caused by the fracture of the 3-inch tubes and cut through the pipes at the junction of the screw and flange. The vertical pressure on the rods being still applied upwards by means of the screw-jacks, the upper tubes are separated from the lower ones at the point of fracture.

The tubes have now to be raised, and to effect this the screw-jacks are removed, and a strong iron ring is screwed on to the top of the upper rod, and is attached by an iron hook and shackle to the end of the flat rope, which winds round the drum of the boring engine. Steam being now admitted into the cylinder, the flat rope is wound round the drum and raises the iron rods, with the fish-head still holding in the under edge of the 3-inch pipes which have been separated from those below them.

As each pipe arrives at the top of the boring it is unscrewed from the pipe next below it, steam pressure being still applied to prevent the rods and pipes from falling back into the boring.

Strong iron clamps are then fixed round the upper part of the second tube. The clamps rest upon two beams of sâl wood, of 14 × 10 inches scantling, which are let into the masonry which lines the upper part of the well. The second rod from the top is also secured by clamps, which are also used for raising the rods, as before described, and which prevents the rods from falling back within the pipes.

The upper rod is now unshackled from the winding rope, and unscrewed from the second rod, and the upper tube and the upper rod are removed from the boring.

The ring is now screwed on to the nut of the second—now the upper rod—and is hooked on to the winding rope. Steam pressure is again applied, until the winding rope is taut and sustains the weight of the rods and pipes, and the clamps that secure the rods and pipes are unfastened. On the rope being wound round the drum, the second pipe is raised in the same manner as the first, the fish-head still holding at the bottom of the tubes; and the process is repeated until all the pipes are brought up.

Several pipes of 5-inch diameter were brought up in a similar manner, the diameter of the fish-head being increased to fit the larger tubes.

E. T. T.

Opinion of T. Oldham, Esq., LL. D., *Supdt., Geological Survey, dated 7th August 1872.*

I beg to acknowledge receipt of your letter No. 927 B—M., dated 2nd instant, and in reply to state that the grounds of hope for success in prosecuting borings for artesian wells near Ambála are exactly those which have been already fully set forth in this office letter, of which a copy is annexed.

There is known to be, and must be, a very great absorption of water along the base of the hill region, of which there is a very limited or no re-appearance at the surface further south, and which therefore, it is most reasonable to suppose, must be found under ground.

The existing boring cannot be successfully carried further down; it was commenced with too small a bore, but others ought, I conceive, to

be tried, and I would recommend boring at least to the sea level if success do not sooner reward the trial

T O.

Copy of letter by H B MEDLICOTT, Esq , *dated 27th May 1867*

I have the honour to acknowledge receipt of your letter No 853 of 14th May 1867, addressed to Dr Oldham, asking for an opinion upon the prospects of an artesian boring at Ambala Pending Dr Oldham's return from Europe in November next, I would submit the following remarks on this interesting and important subject

In Volume III of the Memoirs of the Geological Survey of India, at page 182 of my paper, descriptive of a portion of the North-Western Himalayas, I have briefly described the condition of formation of the Gangetic plains with reference to the prospects of artesian borings Upon general considerations, more or less matter of fact or matter of inference or conjecture, I then expressed an opinion decidedly in favour of such experiments With reference to the definite project now emanating from the Government of the Punjab, I have endeavoured to supplement the independent opinion formerly arrived at by reference to numerous authorities and analogous examples, and I am happy to state that these have proved entirely satisfactory and encouraging I can do no better than to cite a number of these cases, they are so untechnical and intelligible that I hope they may be sufficient to give the Government much confidence in sanctioning the outlay, and in ordering the immediate execution of the project

(*a*)—At Conselice, in the province of Ferrara, on the plains of the Po, which are formed by an unknown thickness of alluvial clays, sands and gravels, an artesian boring was made on account of the deficient supply and the saline qualities of the surface waters (*see* Bull Soc Geol de France, Vol XIV, p 102, 1856 57) The locality is 13 miles distant from the flanks of the Appennines, along which the plains' deposits rest against and upon disturbed strata of upper tertiary age. Water was found at 160 feet in a bed of gravel, and rose to 6 feet above the surface The water bed is in the superficial deposits, the underlying formation was not reached The surface beds are not stated, but I infer from the description that Conselice is but little above the sea level (it was formerly on the coast, though now 22 miles inland), and that the water bed is here far below the sea level, and was probably deposited under salt waters The sweet water now drawn from it is, no doubt, derived by infiltration from the higher slopes at the base of the mountains Success was confidently looked for, based upon arguments such as I have applied to the plains of Upper India

The numerous artesian wells sunk in the Eastern Sahara present stratigraphical conditions essentially like those of the plains of India, great deposits of coarse and fine detritus adjoining and overlying disturbed and denuded tertiary strata The composition and the overlapping arrangement of the beds indicate their mode of deposition by diluvial transportation from the neighbouring mountains The exact thickness of these deposits is not known, but the artesian water lies in them apparently in

the coarser materials, which, as a rule, predominate at the base of the section. The chief features of some of these borings are worth recording here. The work was all done by detachments of French soldiers, the temperature being sometimes at 114°. (*See* Bull. Soc. Géol. de France, Vol. XIV, p. 615, 1856-57.)

(*b.*)—At Oum-el-Thiour, elevation 115 feet, about 50 miles from the edge of the plains, where the elevation is 360, a first spring was reached at 100 feet in quicksand, and rose to within 8 feet of the surface; a second spring at 138 feet in quicksand rose to within 3 feet of the surface; the first jet rose from 178 feet in quicksand, and gave 4½ gallons per minute; a second jet rose from 224 feet in hard sand with kunkur, and gave two gallons per minute; a third jet rose from 264 feet in clear sand, and gave 33 gallons per minute. The deficiency of this spring was accounted for by the proximity of a deep depression of the surface. The chances were considered unfavorable.

(*c.*)—At Famerna, elevation 128 feet, a jet rose from 198 feet in fine sand, giving 990 gallons per minute. The bore was sunk in 39 days.

(*d.*)—At Sidi-Rached, elevation 142 feet, a jet rose from 178 feet in conglomerate, giving 990 gallons per minute. This is 60 miles from the supposed source of supply at foot of hills.

(*e.*)—At Tamelath, a first boring, 198 feet elevation, and a depth of 148 feet in gravel, gave 9 gallons per minute. A second boring at 191 feet elevation, and a depth of 191 feet in conglomerate, gave 33 gallons per minute. These two wells were especially instructive, because of the total want of similarity in the sections of the beds passed through, although the positions were only 120 yards apart, thus showing that success is compatible with great irregularity in the nature of the strata.

(*f.*)—At Oned-el Aleng on the plain of Metidja, which slopes towards the Mediterranean from the north base of the Little Atlas, two borings were made in the deep diluvial deposits. The first boring, at an elevation of 178 feet from a depth of 356 in gravel, delivered 260 gallons per minute at 6 feet below the surface. Annales des Mines, 6th Ser., Vol. IX, p. 333.

(*g.*)—The second well, 4 miles north of the first and 100 feet lower from a depth of 237 feet in gravel, gave a discharge of from 660 to 780 gallons per minute; the former quantity equals nearly a million gallons a day. The first of these wells was sunk in 51 days of 20 hours; the second in 16 days. (*See* Annales des Mines, 6th Ser., Vol. IX, p. 333). In this case also the stratigraphical conditions are similar to those of the Indian plains.

Some particulars of cost and construction may be useful for comparison. I may take the well (*f.*)

	Rs.	Rs.
Freight and tools	1,090	
Labor and supervision	1,174	
Contingencies	181	2,445
132 feet of 8·25 inch tubes	350	
224 „ 10·62 „	765	
158 „ 11·88 „	600	1,715
TOTAL		4,160

The labor was done by military convicts receiving 10 annas per day of 10 hours The work was completed in 51 days of 20 hours

The depth of this boring is a sixth more than that estimated for by Mr Purdon, yet the cost is little more than a fourth, the time of execution also was about a sixth. The ground to be cut through being about identical in the two cases, the discrepancies in time and cost seem vastly greater than can reasonably be accounted for by the different circumstances of Algiers and India The engine and the well are extra items in Mr Purdon's estimate, for which the necessity or advantage is not apparent

The comparison of all the knowable conditions in the cases I have enumerated with those at Ambala and other such positions on the plains of Upper India seem altogether in favor of the latter notably the con-*dition of* *absorption. Although, as I have* pointed ossibilities of failure, the apparent chances can generally be counted upon in undertakings of this nature

Viewing the very extensive and numerous regions of India, more especially in the North-West, in which the want of water is more or less felt, and where conditions obtain apparently and, as far as at present known, analogous to those which have been just described, considering, too, the trifling outlay of time and money requisite under *good management* to obtain very considerable supplies of water by artesian borings, it would surely be well worthy of Government to institute a series of experiments on a really efficient scale. For this it would be necessary to *procure from Europe a set of the most improved tools, and one or more* trained workmen.

H B M.

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872.

Date.	Depth from the surface.	Description of Soil and General Remarks.
1869. 1st to 3rd November.	Sinking a masonry well 6 ft. in diameter and 15 ft. deep.	Erecting machine.
4th November ...	Ditto ...	Native holiday.
5th „ ...	Ditto ...	Nature of soil in well—
6th „ ...	Ditto ...	1st sample 4 feet of surface soil.
7th „ ...	Sunday ...	2nd „ 2 „ fine sand.
8th and 9th November.	Repairing large spur wheel.	3rd „ 3 „ stiff clayey soil. 4th „ $2\frac{1}{2}$ „ fine sand. 5th „ $3\frac{1}{2}$ „ very stiff clay. Total ... 15 feet.
	Boring. Feet.	
10th November ...	27	Stiff brown clay from 15 feet to $26\frac{1}{2}$ feet below surface.
11th „ .	38	Kunkur, $26\frac{1}{2}$ „ to 27 feet below surface.
12th „ ...	41	14 feet of fine sand and a little water from 27 feet to 41 feet below surface, sand falling in; commenced tubing with $9\frac{3}{4}$ inch tubes; put in 4 tubes.
13th „ ...	51	$1\frac{1}{2}$ feet of stiff brown clay from 41 to $42\frac{1}{2}$ feet. 2 „ „ blue „ from $42\frac{1}{2}$ to $44\frac{1}{2}$ „ $5\frac{1}{2}$ „ „ brown „ from $44\frac{1}{2}$ to 50 „
14th „ ..	Sunday.	
15th and 16th November.	61	$3\frac{1}{2}$ feet fine sand 50 to $53\frac{1}{2}$ feet falling in. 3 „ stiff brown clay $53\frac{1}{2}$ „ to $56\frac{1}{2}$ feet. $10\frac{1}{2}$ „ fine sand with water from $56\frac{1}{2}$ to 67 feet.
	69	2 „ stiff brown clay 67 feet to 69 feet put in 7th tube.
17th November ...	76	11 feet of fine sand with water 69 feet to 80 feet.
18th „ ...	83	5 „ of brown clay 80 „ to 85 „ $1\frac{1}{2}$ „ of fine sand 85 „ to $86\frac{1}{2}$ „
19th „ ...	91	$35\frac{1}{2}$ „ of very stiff brown clay from $86\frac{1}{2}$ „ to 122 „
20th „ ...	$97\frac{1}{2}$	
21st „ ...	Sunday.	
22nd „ ...	106	2 feet kunkur formation 122 feet to 124 feet.
23rd „ ...	112	
24th „ ...	118	
25th „ ...	127	4 feet fine sand 124 feet to 228 feet.
26th „ ...	...	Tubing all this day, put in the 10th and 11th tubes, forcing them down with two 10-ton jacks; put in the 12th, 13th, and 14th tubes.
27th „ ...	...	
28th „ ...	Sunday.	
29th „ ...	135	9 feet of sand and clay from 128 feet to 137 feet.
30th „ ...	145	2 „ of sand „ 137 „ to 139 „ 5 „ of „ and clay from 139 „ to 144 „
„ „ ...	...	
1st December ...	148	4 „ of clay from 144 „ to 148 „ sand falling in.
2nd and 3rd December.	158	$2\frac{1}{2}$ „ of kunkur from 148 „ to $150\frac{1}{2}$ feet.
	170	$3\frac{1}{2}$ „ of sand $150\frac{1}{2}$ to 154 feet. 12 „ of dark red clay 154 feet to 166 feet. 4 „ of sand and clay 166 feet to 170 „ $\frac{1}{12}$ „ of shaley formation 170 feet to $170\frac{1}{12}$ feet.

[illegible] at [illegible]'s [illegible]—(contd).

Date.			[illegible]	[illegible] Remarks.
[illegible]			[illegible]	[illegible] to 174 feet [illegible] when they dropped by [illegible]
5th	"	—	[illegible]	The pump [illegible] about 4 feet from bottom of [illegible] [illegible] pump with hook of iron rod, but [illegible] [illegible] to force it up the hook stretched.
6th	"	—	—	
7th	"	—	—	
8th	"	—	—	Tried to pull up the pump with the [illegible] rope, [illegible] [illegible]
9th	"	—	—	15 feet of sand and mud on top of pump; [illegible] 3 feet of it.
10th	"	—	—	Cleared the hole and got an impression of the top of the pump, bore down the tubes 1 foot to [illegible] sand from coming in.
11th	"	—	—	Hooked the pump and forced it up, got it up at 2 [illegible] afterwards cleaning bore and made a [illegible] for pump.
12th	"	—	Sunday.	
13th	"	—	152	6 feet of stiff brown clay from 174 feet to [illegible] feet. 1 foot 6 inches of kunkur 159 [illegible] 1 foot 6 inches of sand 151½ [illegible] On passing through the kunkur the water [illegible] [illegible] in the bore, and in two hours [illegible] 30 feet sand working in at bottom.
14th	"	..	...	Tested the spring at 95 feet below the surface [illegible] [illegible] was 22 gallons per minute, [illegible] [illegible] in 10 minutes, afterwards [illegible] [illegible] were going very stiffly, [illegible] [illegible]
15th	"	..	...	33 feet of sand in the tube, [illegible] and pouring water down [illegible] forcing down the tubes [illegible] stiffly; got down 2 ft. [illegible]
16th	"	..	...	Pouring water down [illegible] using two ten-ton [illegible] the tubes which [illegible] 8 inches
17th	"	...	...	By using the same [illegible] bar, got down 2 feet 6 inches.
18th	"	...	...	By using the same [illegible] got the tubes down [illegible] bore.
19th	"		Sunday.	
20th	"	..	185½	1 foot 6 inches [illegible] surface.
21st	"	...	183	2 feet [illegible]
22nd	"	...	190 4	[illegible]
23rd	"	.	192 6	2 feet [illegible]
24th	"	.	195 6	3 feet [illegible]

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd.)

Date.	Depth from the surface.	Description of Soil and General Remarks.
1869.	*Boring.* Feet.	
25th December ...	Christmas day.	
26th " ...	Sunday.	
27th " ...	199	6 inches clay 196 feet to 196 feet 6 inches; put in the 22nd tube, and forcing them down with two ten-ton jacks and two six-ton jacks.
28th " ...	203	2 feet 6 inches sand from 196 feet to 199 feet. 3 feet 6 inches clay with kunkur 199 feet to 202 feet 6 inches.
29th " ...	207½	8 feet 6 inches sand 202 feet 6 inches to 211 feet; put on the 23rd tube, and forcing them down with two ten and two-six ton jacks.
30th " ...	211	1 foot dark red clay with kunkur 211 feet to 212 feet. } Forcing down tubes with two ten-ton jacks.
31st " ...	214½	1 foot brown red clay with kunkur 212 feet to 213 feet. 1 foot 6 inches sand and clay with kunkur, 213 feet to 214 feet 6 inches. } Forcing down tubes with two ten-ton jacks.
1870.		
1st January ...	New Year's day.	
2nd " ...	Sunday.	
3rd " ...	219	2 feet clay with kunkur from 214 feet 6 inches to 216 feet 6 inches; put on the 24th tube, forcing them down with two ten-ton jacks.
4th " ...	225	3 feet 6 inches clay with kunkur and black spots, 216 feet 6 inches to 220 feet. 3 feet clay with small particles of green sand 220 feet to 223 feet.
5th " ...	230½	11 feet fine sand (very dark colored) 223 feet to 234 feet sand filling in; put in the 25th tube, forcing them down with two six-ton jacks.
6th " ...	238	Put in the 26th tube forcing with two six-ton jacks.
7th " ...	245	2 inches stiff brown clay 234 feet to 234 feet 2 inches. 5 feet 10 inches coarse grey sand 234 feet 2 inches to 240. 6 inches brown clay with kunkur 240 feet to 240 feet 6 inches.
8th " ...	253	9 feet 6 inches brown clayey sand 240 feet 6 inches to 250 feet; but in the 28th tube, forcing with two six-ton jacks. Very stiff red clay with dark-colored shingle from 250 feet to 264 feet; temperature of water in bore 76 feet.
9th " ...	Sunday.	
10th " ...	259 }	2 feet very stiff red clay mixed with kunkur 264 feet to 266 feet.
11th " ...	264 }	
12th " ...	268	6 inches fine soft sand from 266 feet to 266½ feet.
13th " ...	271½	Very stiff brown clay.
14th " ...	273½	
15th " ...	275	The tubes have been forced down to near the bottom of bore. 8½ feet stiff brown clay.
16th " ...	Sunday.	
17th " ...	276	1 foot stiff brown clay with grey spots.
" " ...	278½	2½ feet soft sandy soil.
" " ...	279	½ foot very coarse grey sand with kunkur.
18th " ...	286	7 feet fine soft sand.
19th " ...	...	Forcing down tubes.
20th " ... }	292 }	6 feet coarse sand mixed with small stones.
21st " ... }		

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1879 until the 1st February 1872—(contd)

Date	Depth from the surface	Description of Soil and General Remarks
1870	*Boring* Feet	
22nd January	292¼	¼ foot clay and sand with pebbles.
" "	295	Very coarse sand with pebbles
" "	296	
23rd "	Sunday	
24th "		No progress
25th "	297	Very stiff clay
26th "	298	Sand.
27th "	299	Sandy clay
28th "	300	Sand.
" "	301	
28th January	302	Sand.
29th "	303	Very stiff brown clay with kunkur
" "	304	
" "	305	
" "	306	
" "	307	
" "	308	
" "	309	Depth of water from surface 34 feet
30th "	Sunday	
31st "	310	Sandy clay and mica.
" "	311	" "
" "	312	" "
" "	313	" "
1st February	314	" "
" "	315	" "
" "	316	" "
2nd "	317	" "
" "	318	" "
" "	319	Stiff brown clay
"	320	"
3rd "	321	"
" "	322	"
4th "	323	"
"	324	"
5th "	325	Sandy clay (hard)
" "	326	"
" "	327	"
6th "	Sunday	
7th "	328	Soft dark brown sand
" "	329	" "
"	330	" "
8th "	Boring	
" "	331	Dark grey sand
9th "	332	Stiff brown clay with kunkur
10th "	333	" "
" "	334	" "
11th "	335	" "
" "	336	Dark grey sand.
" "	337	Sandy clay
" "	338	"
12th "	339	Dark grey sand.
" "	340	"
13th "	341	"
14th "	342	Depth of water from surface 36 feet

turn showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd.)

Date.	Depth from the surface.	Description of Soil and General Remarks.
1870.	Boring. Feet.	
	313	Dark grey sand.
14th February ...	314	"
" " ...	315	"
15th " ...	316	"
" " ...	317	"
" " ...	318	"
" " ...	319	"
16th " ...	350	Dark grey sand with kunkur.
" " ...	351	" "
" " ...	352	" "
" " ...	353	" "
" " ...	354	" "
" " ...	356	" "
17th " ...	357	" "
" " ...	358	" "
" " ...	359	" "
" " ...	360	" "
" " ...	361	"
" " ...	362	Stiff red clay.
" " ...	363	Yellow clay and sand.
" " ...	364	" "
18th " ...	365	Dark grey sand.
" " ...	366	"
" " ...	367	"
" " ...	368	Dark grey sand.
19th " ...	369	Depth of water from surface 35 feet.
" " ...	370	
" " ...	Sunday.	Dark grey sand.
20th " ...	371	"
21st " ...	372	
"	373	"
	374	"
22nd " ...	375	"
" " ...	376	Dark red clay.
23rd " ...	377	"
" " ...	378	Dark colored clay.
" " ...	379	"
" " ...	380	Dark colored sand.
24th " ...	381	Dark red clay.
" " ...	382	"
" " ...	383	"
" " ...	384	"
25th " ...	385	Mr. Harrop unwell; natives cleaning machinery.
" " ...	Sunday.	
26th " ...	...	
27th " ...		Dark red clay. Driving and forcing tubes [for]
28th "	386½	Tubes stuck fast.
1st March. ...		Enlarging and deepening well in order to gi[ve] room for the working of the screw-jacks.
2nd "	...	
3rd " ...		
4th " ...		

Return showing the progress on the Artesian well boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd)

Date.	Depth from the surface	Description of Soil and General Remarks
1870	*Boring* Feet	
5th March		
6th "		
7th "		
8th "		*Nil* A larger masonry cylinder of greater depth in course of construction to give room for working a greater number of screw jacks
9th "		
10th "		
11th "		
12th "		
13th to 19th March		
20th to 26th "		
27th Mar to 2nd April		The pressure available is insufficient to move the tubing, extra jacks have been applied for
3rd to 9th April		The screw jacks have been received
15th April	387 10 *ins*	The pipes have been forced down 16 inches under a nominal pressure of 64 tons, assisted by hammering on the top of the pipe The pipes have suffered, and further attempts to force down the $9\frac{3}{4}$ inch tubing have been postponed
16th "		
1st July	390	Red clay
2nd "	391	"
" "	392	"
" "	393	"
" "	394	"
4th "	395	Dark grey sand
" "	396	"
5th "	397	Yellow coarse sand with stones
" "	398	" "
6th "	399	" "
" "	400	Dark grey sand with large stones
" "	401	" "
7th "	402	" "
" "	403	" "
" "	404	Very coarse gravel
8th "	405	"
" "	406	"
9th "	407	"
11th	408	Very coarse gravel with boulders
"	409	"
12th "	410	"
" "	411	"
13th "	412	" "
14th "	413	" "
" "	414	" "
15th "	415	" "
" "	416	" "
" "	417	Very coarse grey sand with large stones and red clay
16th "	418	" "
" "	419	" "
" "	420	" "
		[Depth of water from surface 31 feet 9 inches]

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—contd.

Date.	Depth from the surface.	Description of Soil and General Remarks.
1870.	*Boring.* Feet.	
18th July ...	421	Very coarse grey sand with stiff red clay and black kunkur.
" " ...	422	
" " ...	423	
19th " ...	424	
" " ...	425	Stiff red clay.
" " ...	426	"
20th " ...	427	"
" " ...	428	"
" " ...	429	"
21st " ...	430	"
" " ...	431	"
" " ...	432	Dark silt or running sand.
22nd " ...	433	Red clay (very sandy).
" " ...	434	" "
23rd " ...	435	" "
" " ...	436	" "
" " ...	437	" "
" " ...	438	" "
		Depth of water from the surface 32 feet 6 inches.
25th " ...	439	Red clay (very sandy).
" " ...	440	" "
" " ...	441	" "
26th " ...	442	" "
" " ...	443	" "
" " ...	444	" "
27th " ...	445	" "
" " ...	446	" "
28th " ...	447	Dark silt or running sand.
29th " ...	...	No progress; forcing down tubes.
30th " ...	...	Depth of water from the surface 31 feet 6 inches.
1st August ...	448	Dark silt or running sand.
" " ...	449	Very stiff red clay.
2nd " ...	450	Dark red loamy clay.
" " ...	451	" "
" " ...	452	Dark running sand.
3rd " ...	453	"
4th " ... 5th " ... 6th " ...	...	No progress. Depth of water from the surface 32 feet.
11th & 12th Aug.	454 455	Dark running sand with clay boulders and kunkur.
		Note.—On 8th, 9th, and 10th engaged in forcing down the tubes, consequently no progress in boring. On the 13th with a pressure on the pipes of 80 tons (besides driving), the tube broke at the bottom joint 9 feet from the bottom of bore: work now at a stand-still. Depth of water from the surface 33 feet.
1871. 23rd to 27th May	...	Cleaning the crabs, blocks, chains, &c., for lowering the tubes.

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd).

Date.	Depth from the surface	Description of Soil and General Remarks
1871.	*Boring* Feet.	
28th May	Sunday.	
29th to 31st May	..	Cleaning the crabs, chains, &c, for lowering the tubes.
1st to 3rd June	...	460 feet of tubes 5 inch in diameter lowered in the bore hole.
		A telegram was sent to the Executive Engineer, Derajat Division, to despatch a quantity of flat rope required for the well The rope has not yet been received, and it is requested that instructions may be issued that will cause the despatch of the rope, as without it the boring cannot be continued to a further depth of 30 feet.
4th June	Sunday.	
5th, 6th & 7th June	.	Cleaning out the bore and making new wrought iron jack and shackle for flat rope
8th June	.	Repairing sledge pump and fitting new motion on 5-inch boring bar.
9th "	456	Fine soft sand.
	457	" "
	458	" "
	459	Stiff red clay with kunkur.
	460	" " "
	461	" " "
	462	" " "
10th June	463	Fine soft running sand
" "	464	" " "
" "	465	" " "
" "	466	" " "
		Depth of water from the surface 31 feet
12th "	467	Stiff red clay.
" "	468	"
" "	469	"
" "	470	"
" "	471	"
" "	472	"
" "	473	"
" "	474	"
12th "	475	"
" "	476	"
13th "	477	Running sand.
" "	478	"
" "	479	"
" "	480	"
" "	481	"
14th "	482	"
" "	483	"
" "	484	Loamy clay.
15th "	485	"
" "	486	"
" "	487	Dark sandy clay.
" "	488	"
" "	489	"
16th "	490	"
" "	491	"

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd.)

Date.	Depth from the surface.	Description of Soil and General Remarks.
1871.	*Boring.* Feet.	
16th June ...	492	Dark sandy clay.
" " ...	493	"
" " ...	494	Very stiff red clay.
" " ...	495	" "
17th " ...	496	" "
" " ...	497	" "
" " ...	498	Light sandy clay.
" " ...	499	" "
" " ...	500	Stiff red clay with small stones. Depth of water from the surface 80 feet.
19th " ...	501	Stiff red clay with stones.
" " ...	502	Fine running sand.
" " ...	503	" "
" " ...	504	" "
" " ...	505	" "
" " ...	506	" "
" " ...	507	Very stiff red clay.
20th " ...	508	" "
" " ...	509	" "
" " ...	510	" "
" " ...	511	" "
" " ...	512	" "
" " ...	513	" "
21st " ...	514	Coarse grey sand.
" " ...	515	" "
" " ...	516	" "
" " ...	517	" "
" " ...	518	" "
" " ...	519	" "
" " ...	520	" "
24th " ...	521	" "
" " ...	522	" "
On the 22nd and 23rd no progress, awaiting the arrival of flat rope from Rajanpoor. Depth of water from the surface 50 feet.		
26th June ...	523	Coarse grey sand and kunkur.
" " ...	524	" " "
" " ...	525	" " "
" " ...	526	" " "
27th " ...	527	" " "
" " ...	528	" " "
" " ...	529	" " "
" " ...	530	" " "
28th " ...	531	" " "
" " ...	532	" " "
" " ...	533	" " "
" " ...	534	Stiff clay, boulder, kunkur and sand.
29th " ...	535	" " "
" " ...	536	" " "
" " ...	537	" " "
" " ...	538	" " sand (blowing).
30th " ...	539	" " "
" " ...	540	" " "
" " ...	541	" " "
" " ...		

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd)

Date	Depth from the surface	Description of Soil and General Remarks
1871	*Boring* Feet	
30th June	542	456 86 feet 5 inch tubing gone down
1st July	543	„ „
„ „	544	„ „
„ „	545	456=86 feet 5 inch tubing gone down
„ „	546	Depth of water from the surface 40 feet
3rd „	547	Stiff clay with large kunkur
„ „	548	„ „ „
„ „	549	„ „ „
„ „	550	
		again on the 7th
8th „	551	Very stiff clay with large kunkur
„ „	552	456=96
		Depth of water from the surface 150 to 170 feet
From 9th to 15th July		No progress during the week
		The pipes near the bottom of the bore, it is supposed, again became bent, as the boring bar will not work in the tubes The 5 inch tubes will now be raised in [illegible] es by [illegible] eal of [illegible] ength
„ 16th to 22nd	..	No progress On Friday morning the last tube was taken up The two bottom tubes were bent 1¼ inch, prepared a new shoe and two new tubes for the bottom and commenced to lower them again
		Saturday, total pipes lowered 189 feet *Note*—As the 5 inch tubes were brought up, the bore hole filled in until they were brought level with the bottom of the 7 inch tubes
„ 23rd to 29th		No progress On lowering down the 5 inch tubes to a depth of 459 feet, it was found that the bottom 7 inch tube had become detached from the others and now lies across the hole
		Efforts have been made to straighten the tube with a large iron bar cigar shaped, but until now they have been unsuccessful
„ 30th July to 5th August		No progress during the week The whole of the 5 inch tubes have been again brought up, and a powerful instrument constructed to cut up the detached broken 7 inch pipes.
„ 6th to 12th August		No progress
		In trying to cut up the detached 7 inch pipe, it has been driven further into the sand and clay, and the 7 inch tubes have been forced down after it to a depth of 15 inches, no more 7 inch tubing on hand
„ 13th to 19th August	.	No progress
		Lowering the 5 inch tubes again
„ 20th to 26th August		No progress

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd.)

Date	Depth from the surface	Description of Soil and General Remarks
1871	*Boring* Ft In	
		A sample of flat rope has just been received from Messrs Harton and Co, Calcutta, that will answer very well to replace the worn rope, and a length of 1,000 feet has been ordered
9th October		Unable to pass the pump or auger down the 5 inch tubes owing to the latter being bent Some of the joints of the tubes have been forced asunder, in consequence of the great pressure (44 tons) that had to be exerted to force the tubes down, showing that a greater pressure could not be put on the tubes
10th „		A small pump was attached to four 3 inch pipes, and the whole lowered down the 5 inch tubes, but the pump and 3 inch pipes stuck fast in the joint of the 5 inch pipes
11th „		The pump and 3 inch pipes extricated with considerable pressure
12th „		Preparing to lower the 3 inch pipes, making sludge pump, clamps, and auger
13th „		Erecting beams, blocks and clamps for lowering the 3 inch pipes, which will weigh altogether 3½ tons
14th „		Same as on the 13th
16th „		3 inch pipes lowered to a depth of 250 feet
17th „		„ „ „ 275 feet on a level with bottom of 5 inch tubes
18th „		25 feet of sand in the pipes, boring with rods and pumping out the sand
19th „		Pumping out the sand, tubes lowered 1 foot, total depth 526 feet
20th „		Pumping and using the auger and boring rods Pipes lowered 1 foot 6 inches
21st „		Pumping out the sand, pipes went down 1 foot 9 inches, total depth 529 feet 3 inches
	529 3	The new rope for the 3 inch pipes is being made at Calcutta, but will not be ready for three weeks The Agent, Scinde and Delhi Railway, has been asked if he can lend a rope of 1¼ inch or 1½ inch diameter for boring in the 3 inch pipes to prevent the delay caused by boring with rods until the Calcutta rope is ready
23rd „	529 3	Holiday
24th „	533 0	3 inch tubes lowered 3 feet 9 inches
25th „	534 9	„ „ 1 foot 9 „
26th „	537 0	„ „ 2 feet 3 „
27th „	539 3	„ „ 2 „ 3 „
28th „	541 11	„ „ 2 „ 8 „
		Pipes going down well with their own weight without pressure, stratum of thick clay with a small quantity of sand and kunkur
		The boring during the past week was carried on entirely by boring orders, and in thick clay stratum this is found to be as effectual as boring with the rope and auger
30th „	544 5	3 inch tubes got down 2 feet 6 inches
31st „	546 11	„ „ 2 „ 6 „
1st November	549 8	„ „ 2 „ 9 „

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869, until the 1st February 1872—(contd.)

Date.	Depth from the surface. Boring. Ft.	In.	Description of Soil and General Remarks.
1871.	551	6	3-inch tubes got down 1 foot 10 inches old depth to which the 5-inch pipes were got down.
2nd November ...	552		Sand.
3rd ,, ...	553		,,
4th ,, ...	554		,,
5th ,, ...	554		*Note.*—The sand is blowing in at the bottom, filling the tubes as much as 26 feet at a time. It is found necessary to apply a force of 6 tons to get the tubes through the bed.
6th ...	555		4 hours occupied in pumping out sand.
7th ...	...		5 ,, ,,
8th ...	556	3	Water had to be poured into the tubes to resist the blowing in of the sand.
9th ,, ...	557	9	Tubes raised 4 feet, and sand washed out and again lowered. The boring is being carried on entirely by rods. A stratum of very stiff clay with a small quantity of sand is now being worked in.
10th ,, ...	560	3	
11th ,, ...	563	0	Stiff red clay.
13th ,, ...	565	9	Clay with slight mixture of sand; pressure of 6 tons on the 3-inch tubes.
14th ,, ...	568	9	Put on the 63rd 3-inch tube.
15th ,, ...	571	9	Very stiff red clay at 578 feet.
16th ,, ...	574	6	Pressure of 8 tons exerted on the tubes.
17th ,, ...	577	6	The 3-inch tubes are going down very fairly; work being carried on entirely by boring rods; but Messrs. Harton and Co., Calcutta, have written to say that the new rope for the 3-inch tubes will be ready in a few days, and when this is received much time will be saved in pumping.
18th ,,	580	4	Very stiff clay.
20th ,, ...	581		,, ,,
	582		,, ,,
	582	10	,, ,,
	583		,, ,,
21st ,, ...	584		Fine black sand.
	585		,, ,,
	586		,, ,,
	587		,, ,,
	587	9	,, ,,
	588		,, ,,
23rd ,, ...	589		,, ,,
	589	5	,, ,,
	590		,, ,,
24th ,, ...	591		,, ,,
	591	3	,, ,, mixed with pebbles.
	592		,, ,,
25th ,, ...	593		Total depth.
	593	7	A pressure varying from 16 to 30 tons exerted to force down the 3-inch pipes.
			Note.—Water 46 feet from the surface.
28th ,, ...	597	11	Black fine sand, white small admixture of pebbles.
29th ,, ...	602	5	Loamy clay at depth of 661 feet.

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872—(contd)

Date	Depth from the surface	Description of Soil and General Remarks
1871	*Boring* Ft In	
30th November	605 11	Loamy clay at 66 feet, 3 inch tubes lowered
1st December	608 7	Loamy clay, pressure of 32 tons exerted to force down the tubes
2nd ”	609 7	Loamy clay, pressure of 30 tons exerted to force down the tubes
3rd ”	611 1	Loamy clay, pressure of 30 tons exerted to force down the tubes
4th ”	613 1	Very loamy clay
5th ”	615 7	Soft clay with kunkur, small pebbles at 615 feet.
6th ”	619 1	Dark red clay at 617 feet 6 inches
7th ”	621 1	Dark red clay
8th ”	623 7	” ”
9th ”	626 1	Lighter coloured clay at 625 feet, very stiff red clay with small admixture of kunkur at 626 feet A pres [illegible] from Calcutta on the 7th instant
11th ”	628 1	Stiff red clay with a little kunkur Attached the 69th tube 3 inch diameter Pressure of 32 tons on the tubes
12th ”	630 4	Red clay at 630 feet Pressure of 30 tons on the tubes
13th ”	631 10	” ” ”
14th ”	634 4	” ” ”
15th ”	636 4	” ” ”
		70th tube attached, tubes slightly bent
16th ”	638 0	Red clay, very stiff
		The new flat rope has just arrived
18th ”	639 10	Stiff red clay at 638 feet 6 inches
19th ”	641 10	Very stiff black clay at 641 feet This is a new variety of clay, and the first of this description that has been met with.
20th ”	643 4	” ” ”
21st ”		Thickness of stratum of black clay only 3 feet
22nd ”	644 10	Stiff red clay with slight admixture of kunkur at 644 feet
23rd ”	647 4	556=191
		Pressure of 40 tons found necessary to force down the 3 inch tubes The new flat rope for the 3 inch tubes arrived from Calcutta during the week, and the work of pumping is much expedited Boring has still to be continued with rods as there is not a ratchet shaped plate for turning the boring rod in the 3 inch tubes, the size of the tubes being too small to allow of such an arrangement
25th ”		Christmas day
26th ”	649 10	Stiff red clay with a little kunkur
27th ”	652 1	Loamy clay at 652 feet
28th ”	654 7	
29th ”	657 3	
30th ”	660 1	Very stiff red clay
		Bottom of the bore 15 feet below the tubes no sand has been met with for the last 50 feet
		Pressure on tubes 40 tons

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1879 until the 1st February 1872—(contd).

Date.	Depth from the surface.		Description of Soil and General Remarks.
1872.	*Boring.* Ft.	In.	
2nd January ...	...		Yesterday Mr. Harrop reported that the 24 feet 3-inch tubes from the top of the well had broken at the flange. He has succeeded in drawing up the upper 24 tubes, and work will be proceeded with. The *fracture of* the tube shows that the 3-inch pipes are not strong enough to resist a pressure of 40 tons, and it is not probable that they can be forced down more than a few feet further.
„ „ ...	660	1	226 feet from the surface; the 3-inch tubes fractured under a pressure of 44 tons; and as nothing could be got down past the fracture, the upper 24 tubes were brought up.
„ „ ...	...		Employed drilling through the obstruction.
3rd „ ...	...		Succeeded, but found another at 328 feet below surface.
4th „ ...	...		And another at 430 feet.
5th „ ...	...		Passed the third obstruction, and met with another at 580 feet below the surface.
6th „ ...	...		*Note.*—The obstruction is probably caused by a piece of the fractured pipe having fallen into the tube.
8th „ ...	...		Passed the obstruction in the 3-inch tubes at 580 feet, and met with another at 646 feet in the bottom tube. This was also passed.
9th „ ...	661	7	Boring below the bottom of 3-inch tubes.
10th „ ...	663	4	This boring may be continued for a few feet lower below the bottom of the tubes, but the 3-inch tubes cannot be got down lower without the whole being brought up and again lowered from the top.
11th „ ...	665	4	
12th „ ...	667	10	
13th „ ...	670	6	
15th „ ...	672	2	Loamy clay.
16th „ ...	674	2	„
17th „ ...	675	8	„
18th „ ...	678	5	Hard dry sandy clay. This earth seems to harden when exposed to the air.
19th „ ...	680	3	„ „ „
20th „ ...	682	3	„ „ „
			The boring is now 27 feet 3 inches below the bottom of the tubes. The sand does not fall in, and fill the bore as much as would be expected, considering the depth of the bore below the bottom of the tubes.
22nd „ ...	684	6	Very stiff yellow clay and kunkur at 683 feet.
23rd „ ...	686	0	„ „
24th „ ...	688	0	„ „
25th „ ...	689	6	Yellow clay.
26th „ ...	690	6	Pumping occupied five hours; clay beginning to fall in.
27th „ ...	693	0	The bottom of the bore is now 38 feet below the bottom of the 3-inch tubes.
29th „ ...	695	6	Soft sandy clay at 693 feet.
30th „ ...	698	3	„ „
31st „ ...	700	0	At this depth the sides of the bore began to fall in, the bottom of the bore being 46 feet below the bottom of the 3-inch tubes.
			Received instructions from Government to take up the 3-inch tubes and endeavour to lower them to a greater depth.
1st February ...	...		Preparing to bring up the 3-inch tubes.

Return showing the progress on the Artesian well-boring at Ambála from the 1st November 1869 until the 1st February 1872,—concld.

Date	Depth from the surface	Description of Soil and General Remarks
1872	*Boring* Ft In	
2nd February		Brought up the three top tubes of 3 inch diameter, the lower one being very much damaged and split for a length of 6 feet
3rd „		A good hold was taken of the 3 inch, but did not succeed in bringing them up The fish head implement used for taking hold of the tubes broke, and broken pieces of the 3 inch tubes seem to have become jammed between the 5 inch and 3 inch tubes The party of six sappers employed on the well left Umballa on the 3rd, having been ordered to join their company proceeding to Peshawur
5th to 12th February	700	Tubes being brought up in accordance with instructions from Government

E T THACKERAY, *Captain, R E,*

Executive Engineer, Lower Sirhind Division

Narrative Report on the Artesian Well at Sabzalkot, Southern Derajat, Punjab, by P. S. McGowan, C.E., *Officiating Executive Engineer, Mooltan Provincial Division.*

1. *Best locality for boring.*—After much consideration as to the most suitable locality for experimenting on an artesian boring for supplying the garrison of the Sabzalkot outpost commanding the Sharee, Chook and Pitook passes in the hills, on the south-western frontier of the Punjab, between the Sharee and Chedgee rivers, with sweet and drinkable water, it was finally decided, from a military point of view, not to abandon the ruinous outpost then existing at Sabzalkot, but to entirely reconstruct it and to benefit with a view to economy and time by commencing the bore at 230 feet below ground level, this being the depth of the bottom of the well then existing within the fortified walls of the outpost. From the strata exhibited in the 230 feet of excavation of the old well, it was known that pebble and boulder strata would have to be bored through were work commenced from the surface of the ground; the starting on ground level would have facilitated considerably the haulage of tubes to be lowered, haulage of plant, examination of excavated material, and given more room for working the screw-jacks, and the workmen, and to supervising the work in progress, but all these advantages counterbalanced that of having to pierce loose pebble and boulder strata which have heretofore proved more difficult and expensive to bore through than solid rock, even with the best machinery.

2. *Situation of Sabzalkot outpost.*—The Sabzalkot outpost is in the Rajanpur sub-division of the Dera Ghazi Khan district in the Southern Derajat of the Punjab province, and situated near the foot of a long slope at the base of the hills forming the south-west frontier of the Punjab, about 22 miles west of the frontier station of Rajanpur. The slope is of varying width and composed apparently of the debris of the higher hills 12 miles to the west.

3. *Description of old well in outpost.*—The old well in this outpost excavated prior to 1857 is 230 feet deep, 9 feet in diameter for the first 24 feet below ground surface, having its sides for these 24 feet below ground level encased or supported by a wooden framework, the next 192 feet in depth of excavation varied in the diameter from 6 to 9 feet and passed through various strata of soil described in the annexed section. The diameter at the end of this section of 192 feet, or 216 feet below ground level, was 11 feet; from this point a steining of masonry, 1½ feet thick, built prior to boring operations being taken in hand, continued downwards for 14 feet, or a total depth of 230 feet below ground surface.

4. *Water in the old well.*—It is believed water collected in the well by mere infiltration from the sides. No spring existed, the water was brackish and tarnished brass vessels, and was totally unfit to be drunk by either men or animals.

5. *Former means of water-supply for the garrison.*—Drinkable water had, therefore, to be brought for the garrison, which consisted of 26

Cavalry and 7 Foot, or 33 men and 26 horses, in leather bags or pakhals on camels, from a distance of 8 miles, and in the hottest months of summer, sometimes from *Asni*, 15 miles distant, at an average annual cost of Rs 600

6 *Object for undertaking the Artesian boring* —Prompted by these circumstances it was decided to experiment on a deeper boring in search for a supply of pure and sweet water than any that had heretofore been undertaken by excavation of wells in that part of the province

7 *Description of and method of employing machinery* —The locality for the experimental artesian boring having been finally decided upon, measures were taken in 1869 to transfer the plant and machinery lately used for the artesian boring at Ambala for employment at Sabzalkot The machinery employed, and the method of working it, have been so fully described with illustrations, *vide* "Professional Papers on Indian Engineering," 1st series, April 1870, extra No III A, page 106 *et seq*, and 2nd series, May 1874, No XII, page 117 *et seq* respectively, that it is needless here to recapitulate either a description of the plant or the method of using it

8 *Commencement of work by steining lowest 24 feet of well* —Work was taken in hand at the latter end of 1870, the first thing undertaken being the steining of the sides of the well for a height of 24 feet, commencing from a height of 216 feet below ground surface, or just above the old masonry, $1\frac{1}{2}$ feet thick, which extended for a depth of 14 feet downwards, the burnt brick in lime masonry was carried up perpendicularly for 24 feet, 2 feet thick, and giving the well a clear internal diameter of 9 feet, so as to leave sufficient room for fixing the timber platforms on which to work the jacks

9 *Boring with $9\frac{3}{4}$ inch tubes diameter commenced at 216 feet and completed at 410 feet below surface* —After the steining of the well for a height of 24 from 216 feet below ground surface, just described, had been completed, an artesian boring with $9\frac{3}{4}$ inches internal diameter tubes was taken in hand, the water level in the old well prior to actual boring being 224 feet below surface, and the supply 40 gallons per hour, this water level, however, varied, rising at times 2 feet to 222 feet below ground surface Boring operations commenced in November 1870 under the immediate supervision of Mr Harrop, the Engineer, under whose management a similar artesian boring at Ambala was effected. In March 1871, or about 5 months afterwards, the twenty-two $9\frac{3}{4}$ inch tubes available were reported to have been utilized in tubing from a point 216 feet below surface, or 8 feet above the level of the water in the old well to a total depth of 410 feet below ground surface, the stratum penetrated by the lowest $9\frac{3}{4}$ inch tube was of coarse gravel and boulders, bearing an abundant supply of water, so firm and stiff as to admit of the bore standing untubed for the last 10 feet of its depth, so that the last 9 feet of the length of the boring (1[illegible] feet to 19[illegible] feet [illegible] untubed, this length of 9 feet, was [illegible] 7 inch pipes commenced in January 1873, when further [illegible] made to force the $9\frac{3}{4}$ inch diameter tubes [illegible] the stratum [illegible] gravel and boulders

10. *Water struck at 410 feet [illegible]* —The [illegible] coarse gravel and boulders, at 410 feet [illegible]

plentiful supply of water, which rose in the pipes to a height of 220 feet below ground surface, or 4 feet higher than level of the water in the old well and fell only 8 feet in the tubes when pumped at the rate of 400 gallons per hour; the water was clear and drinkable, but unfortunately, when not pumped regularly in large quantities, stagnated and was subsequently reported to be brackish to some extent, so much so that the garrison ceased to drink it, although it was drawn in small quantities for cattle which did not seem to suffer from disease of any nature by using it, the garrison obtaining their drinking water either from Asni, 15 miles distant, or that collected by rainfall in a pool close to the outpost.

11. *Question of continuing bore with smaller pipes.*—The experimental bore with 9¾-inch tubes to a depth of 410 feet below surface not having proved a success, it was decided to continue the bore for a further depth of 200 feet with tubes of a smaller internal diameter, *viz.* 7 inches, of which there were 33 available, each 9 feet long, the object in view being that of striking a water-bearing stratum that would yield sweet water such that would not stagnate or turn brackish if drawn in a small quantity only, *viz.*, 120 gallons daily, sufficient only to meet the requirements of the outpost garrison.

12. *Resumption of work in January* 1873.—On resuming work in January 1873, the level of the water in the tubes was found to be 246 feet feet below ground surface, or 22 inches below that in the old well, and on pumping for two months continuously at the rate of 360 gallons every 24 hours, the water still continued to be of a bad quality; it was consequently supposed that the brackish water in the old well had access to the interior of the 9¾-inch tubing; such, however, proved afterwards not to be the case.

13. *Analysis of water struck at 410 feet below ground level.*—In November 1873 two bottles of the water yielded by the stratum of coarse gravel and boulders at 410 feet below surface, were sent to the Chemical Examiner to the Punjab Government, at Lahore, for analysis. The result of the analysis was as follows:—

Total hardness.	Permanent hardness.	Total solid grains.	Principal Salts.
10·1	5·5	252·0	Chloride and sulphate of soda and carbonate of lime and magnesia. Offensive taste and odour from presence of ammonia and sulphuretted hydrogen.

The water was objectionable on account of the large amount of saline matters. The sulphurretted hydrogen and ammonia were probably due to decomposition of sulphate and organic matter resulting from the water having stood so long before the anylysis could be undertaken; it was unfortunately allowed to stand in the bottles for about two months before the analysis was made, so that this test can hardly be considered a very fair one.

14 *Refixing of machinery in disuse since* 1871 —Owing to the machinery having been in disuse since March 1871, when the $9\frac{3}{4}$ inch diameter boring came to a close, the several parts had rusted very much and took four months to clean thoroughly and put together in working order again, when in 1874 further boring had been finally decided upon

15 *January 1874, flat rope found to be useless and bore choked to 219 below surface* —In January 1874, when all the requisites were ready for prosecuting further boring, it was discovered that the flat rope employed for raising and lowering the pump had also decayed and two round ones of $1\frac{1}{4}$ inch diameter were sewn together and used in lieu of the flat one, but failed owing to their twisting, and had eventually to be substituted by a new flat rope of moonj, 2 inches wide and $\frac{1}{2}$ inch thick, which took considerable time to make With all these delays however, work on actual boring was resumed on the 3rd March 1874, when the bore was found to be choked with silt, debris from above, and a dip pump formerly in use, up to a height of 219 feet below surface, or 5 feet above level of water in the old well The upper 192 feet in height of the old well were not steined with brick masonry, and the choking was caused chiefly by a portion of the unlined sides of the well falling in In remedying the accident a portion of the dip pump was taken out as well as the silt and debris, but the rest of the dip pump fell to the bottom of the bore

16 *Extended wooden steining 16 feet lower down* —Before the boring with 7-inch tubes could be proceeded with, the unsteined sides, especially the uppermost, 16 feet in height, shewed signs of falling in, and consequently actual boring with the 7 inch tubes was postponed owing to the danger labourers and others would be exposed to in venturing below on to the platform to work the screw-jacks and pumps About November 1874 a wooden steining or framing was commenced at a depth of 24 feet below surface, and carried down 16 feet giving a total depth of 40 feet steined with wood from the top, as also 38 running feet with masonry from the bottom of the old well, or a total of 78 feet out of a total depth of 230 feet steined

17 *Further efforts to lower $9\frac{3}{4}$ inch tubing below 410 feet from surface* —After this work of boring lower was commenced, and before proceeding to lower the smaller diameter 7 inch tubes, further efforts were made to lower the $9\frac{3}{4}$ inch tubing with the aid of two six ton jacks beyond the stratum of coarse gravel and boulders, but besides tubing the last 9 feet of the bore, actually first executed in 1871, from 185 to 194 feet below surface and left untubed then, nothing was done, and the $9\frac{3}{4}$ inch tubing for want of more powerful jack power, consequently came to a stand still at 410 feet below surface of ground The bore was now cleared of silt and the broken dip pump that fell to the bottom in March 1874 forced to one side

18 *May 1875—lowering of 7 inch diameter tubes commenced* —After these preliminary operations, on the 10th May 1875 lowering the 7 inch tubes commenced, the work progressed satisfactorily for one month till the 10th June 1875, until the lowest 7 inch diameter tube reached a stratum of pebbles and sand (No 58), 421 feet below ground surface, or 11 feet below the end of the $9\frac{3}{4}$ inch diameter tubing, the 7 inch pipes could not be forced through this stratum of coarse sand and pebbles 1 foot thick with the two six ton jacks available, and work on actually boring lower down ceased till more powerful jack power could be obtained

19. Steining well with brick work resumed in May 1877.—In the mean time as debris from the remaining unlined portions of the sides of the well was continually falling in and choking the bore, it was decided upon carrying up the brick-work steining, 1 foot thick, to ground surface, the lowest 38 feet having already been lined with brick-work, thus leaving a height of 192 feet to build up. Work on this steining was started in May 1877, and by the 10th June of the same year a circular steining, 1 foot thick, clear internal diameter of well being 9 feet, had been carried up perpendicularly for a height of 70 feet, so that a total depth of 108 feet out of 230 feet depth of the well's excavation had been lined, and then was only stopped for want of carriage for bricks, which unfortunately for want of suitable soil could not be manufactured at site.

20. Boring with 7-inch tubes from 421 to 524 feet below surface commenced in July 1877.—New and more powerful jacks having been now obtained, the boring with 7-inch tubes, which last stopped on the 10th June 1875 at 421 feet below surface, was again started on the 3rd July 1877, more than two years afterwards, with a pair each of 10 and 12-ton jacks; the pipes penetrated under a pressure of 44 tons the stratum No. 58 of pebbles and coarse sand through which they could not be forced, in June 1875, with a pressure of 12 tons, the maximum the two six-ton jacks then available could exert. After passing this stratum the 7-inch tubes were lowered comparatively easily for a depth of 102 feet from 422 feet to 524 feet below surface in about 4½ months, which gives, including time spent in remedying accident, nearly one foot a day of actual boring. The boring bar actually reached a depth of 526 feet below surface, although the 7-inch tubes stuck fast 2 feet higher up, at 524 feet below surface of ground; boring operations with the 7-inch diameter tubes finally ended on the 6th December 1877, when it was found impracticable to force the 7-inch tubes ending at 524 feet below surface in the stratum of clay 26 feet thick on to the stratum of coarse sand and pebbles at 526 feet below ground surface, or 2 feet lower down, with a jack power of 44 tons, the maximum available.

21. Difficulty experienced in taking out insoluble clay from bottom of bore.—In lowering the 7-inch tubes from 422 to 524 feet below surface, the average pressure exerted was 12 tons, which sufficed to lower the tubes through the strata of stiff clay and sand met with in that length of 102 feet. Considerable delay was, however, caused by the difficulty experienced in taking up the stiff clay after it had been excavated, as it was insoluble, more especially so when the bore deepened and the water in the tubes was as much as 300 feet deep, which rendered the work of the boring bar less effective.

22. Rush of fine sand into bore on striking water-bearing strata.—When the strata of sand were hit upon, as a rule a plentiful supply of water was obtained, but the influx carried in a considerable quantity of fine sand into the bore which delayed boring operations; as also the falling-in of a *moonj* rope, 40 feet long and 1 inch in diameter. On the 20th September 1877 the rope stuck fast in the pipes, after the silt in suspension in the water settled, and had eventually to be cut out.

23. Stratum No. 74, water-bearing 489½ feet below surface.—On the 2nd October 1877 a stratum (No. 74) of sandy clay, 1½ feet thick, was bored through from 489½ to 491 feet below surface, when water

appeared in the bore and rose to 224 feet below ground surface, which, after three hours' pumping with the dip pump at 187 gallons per hour, fell only 7 feet, the water in taste was similar to that before met with,—brackish

24 *Clay stratum No 77 struck and water shut off from bore*—On the 8th October 1877 clay was met with, stratum No 77, when the water was shut out from the bore and did not appear again till a stratum of sand (No 78), 1 foot thick, was entered at 499 feet below ground surface, on the 10th October 1877 this flow of water into the bore was again cut off

25 *Stratum of clay 26 feet thick reached at 500 feet below surface*—On the 11th October 1877, the tubes entered a stratum (No 79) of clay, 26 feet in thickness, extending from 500 to 526 feet below surface

26 *Accident to wad cutter*—In piercing this clay stratum on the 16th October 1877 an accident occurred, the wadcutter got jammed and the *moonj* rope to which it was attached, an old one three years in use, broke, the wadcutter and rope were, however, fished out by the 19th of the same month and the bore pumped dry, the water in the tubes being that accumulated from the leakage through the imperfect joints of the 7-inch pipes

27 *Stratum No 80, pebbles and coarse sand at 526 feet below ground surface*—After passing through 24 out of 26 feet of the stratum of clay, or 524 feet below surface, the 7-inch tubes stuck, but the boring bar reached a layer (stratum No 80), 2 feet thick, of coarse gravel and sand yielding a plentiful supply of water, which rose to a height of 224 feet below surface of ground in the tubes On the 24th October 1877, pumping for four hours, at the rate of 221 gallons per hour, was taken in hand, and the water in the bore lowered 86 feet from 224 to 310 feet below surface, but on the following morning was found to have again risen to 224 feet below surface On reaching this stratum of pebbles and coarse sand a great rush of silt into the bore ensued, choking the tubing for a height of 22 feet from the bottom, the lowest 2 feet of bore, 224 to 226 feet, being untubed, the water yielded by this stratum was also brackish On the 5th November 1877, the bore was again pumped and the level of the water lowered 140 feet, from 224 to 364 feet below surface, while the tubes during the pumping silted up for a height of 19 feet from the bottom of the bore

28 *End of 7-inch tubing at 524 feet below surface*—The 7 inch diameter tubes finally rested at 524 feet below ground surface, and could not be forced on to the stratum of pebbles and coarse sand with the maximum available pressure of 44 tons, and as two 12 and one 10 ton jack had their endless screws damaged in attempting to force the tubes lower, further endeavours were abandoned, and the 7-inch diameter boring came to an end at 524 feet below ground level on the 6th December 1877

29 *Variations in level of water in tubes*—Generally, throughout the 7 inch boring operations, there was a scanty supply of water from the bottom of the bore, at times hardly enough to feed the engine's boiler, and as a rule, when a stratum of firm and plastic clay, very insoluble and consequently difficult to take up, was met, very little or no water entered the bore from the bottom, but accumulated from the leakage

into the 7-inch tubes through their ill-fitting joints with one another, and these facts account for the variations in the level of the water in the tubes at different stages of the boring operations.

30. *Leakage of water into the 7-inch tubing.*—The leakage into the 7-inch tubes is thus accounted for. When the lower end of the pipe (7 inch) enters a stratum of clay, no water rises in it from the bottom of the bore, but the $9\frac{3}{4}$-inch tubing, encasing that of 7-inch diameter, contains water, being fed from the water-bearing stratum of coarse gravel and boulder, 410 feet below ground surface, on which its end rests, it will be noted that there was a space of $\frac{5}{8}$ths of an inch all round between the external face of the 7-inch, and internal face of the $9\frac{3}{4}$-inch diameter pipes, where the water rising from the gravel and boulder stratum 410 feet below ground surface was contained, and it was this water that found its way through the joints of the 7-inch tubes occurring between 410 and 424 feet below surface into the bore.

31. *Exclusion of leakage into 7-inch tubes.*—Although attempts to exclude the leakage from the 7-inch tubes by caulking the $\frac{5}{8}$th-inch space all round with hemp failed, yet were a stratum yielding sweet water struck lower down it could have been drawn uncontaminated after a short time, it is believed; as after actual boring operations ceased and the 7-inch tubes, fitting loosely into those of $9\frac{3}{4}$-inch diameter, had been stationary for some time, they would have had their joints closed by rust.

32. *Completion of brick steining.*—The 7-inch boring last described having come to a stand at 526 feet below surface, and further boring with tubes of a smaller diameter not having then been determined upon, the opportunity was taken, prior to receipt of orders, to complete the steining of the well with brick work; the brick lining was last described as completed to a height of 108 feet from the bottom, leaving a height of 230 feet—108 feet =122 feet to build. Whilst boring operations with 7-inch tubes were in progress, bricks were manufactured for completing the steining of the well to ground level; they were not made at site, and had to be conveyed a long distance after being removed from the kilns. Carriage for them could not be procured in the winter of 1876-77, and the summer of 1877 setting in delayed work in lining the sides of the well till there was a cessation of boring operations with the 7-inch tubes, when work was commenced and the brick-work carried up 1 foot thick perpendicularly for a further height of 33 feet, giving a length of 141 out of 230 feet of steining completed to within 89 feet of ground level. From this point it was considered advisable to carry up the brick-work, decreasing the internal diameter of the well from 9 feet to 6 feet at ground level. The work was proceeded with vigorously and finished by the 19th of February 1878, or in about $2\frac{1}{2}$ months' time, thus completing a brick-work steining 230 feet in depth.

33. *Boring with pipes 5 inch in diameter.*—In the mean time sanction was obtained to continue the bore to a total depth of 600 feet below surface (the 7-inch tubes having only reached 524 feet) with tubes of 5-inch internal diameter, which were in store. Before commencing operations, however, two entire pipes and a length of $3\frac{1}{2}$ feet of a third of 7-inch diameter pipes had to be removed to make room for lowering the 5-inch tubes.

34 *Lowering 5-inch tubes commenced* —Lowering the 5 inch tubes into those of 7-inch internal diameter commenced on the 17th March 1878, and by the 3rd April following the first set of thirteen tubes had been let down On the 11th of the same month lowering the second set of thirteen tubes began and was completed by the 22nd April 1878

35 *Accident to wooden gauge in ascertaining coupling of first with second set of thirteen 5 inch diameter tubes* —To ascertain whether this second batch of thirteen 5-inch tubes had fairly coupled with the first thirteen lowered, a plug or piston of tamarisk wood 3 feet 4 inches long and $4\frac{3}{4}$ inch diameter was lowered, it got jammed in the bore having expanded by soaking in the water and could only be extracted by raising the last set of 13 tubes sent down, all however, were not taken up to the surface, but only six of the uppermost, the piston being found closely fitted in the last of these, heat was applied when the wood contracted and was forced out, this accident delayed boring operations for a fortnight

36 *Re lowering second set of thirteen 5 inch diameter tubes* —On the 3rd May 1878, re lowering the second set of thirteen 5 inch diameter tubes commenced and reached the end of the 7 inch tubing At 525 feet below ground surface they were forced through the last 2 feet of the stratum of clay 26 feet thick and ending at 526 feet below surface on to stratum No 80 of pebbles and coarse sand first bored to on the 22nd November 1877 (*vide* under head 27 of this report)

37 *A*[illegible]

surface —[illegible]

surface till [illegible]

sandy clay, 6 inches thick, overlying stratum No 84 of 1 foot of sand, when the tubes, although jacked down with a pressure of 12 tons on closing work in the evening, during the night of the 31st lowered by their own gravity 1 foot through stratum No 84 and rested on stratum No 85 of clay 2 feet thick The tubes in thus unexpectedly descending [illegible] a few of the uppermost [illegible] n which the screw jacks [illegible] tube from the bottom so that 35 entire and a portion of the 36th tube descended one foot, whilst the rest of the 36th tube remained fast with the few upper ones clamped to the platform, the broken tube was cut out and replaced in three days' time

38 *Water-bearing stratum No 86 met with* — After piercing No 85 of clay, 2 feet thick, water was struck, on the 10th June 1878, in stratum No 86 of sand and pebbles 1 foot in depth at 535 feet below ground surface, silt was forced into the tubes for a height of 12 feet from the bottom by the force of the water and took two days to clear out

39 *Water again struck at 537 feet below ground surface* —The next stratum No 87 was of clay, after passing which water was again struck on the 15th June 1878, in stratum No 88, at 537 feet below ground surface, here there was a great influx of silt (coarse sand), which choked the tubes to a height of 24 feet from the bottom The silt was coarse and great difficulty was experienced in drawing it up, owing to the shell pump valves and plunger getting jammed with it, the result being that no actual boring could be done for six days Boring was stopped for three weeks and

resumed on the 11th July. By the 17th of that month stratum No 99 of clay, one foot deep, was reached, or a depth of 516 feet below ground surface; in the last $6\frac{1}{2}$ feet depth of boring silt alone for a height of 27 feet in the tubes had to be taken up, the large quantity of silt in the pipes being attributable to the sandy strata bored through latterly.

40. *Water struck at $551\frac{1}{2}$ below ground surface.*—From the 18th to 31st July 1878 strata Nos. 99 to 105 were bored through, the only circumstances to notice in boring between 516 and 561 feet below surface being that stratum No. 102 of sandy clay, 2 feet thick, at $551\frac{1}{2}$ feet below ground surface, had water in it, and that on the bore reaching stratum No. 105 of firm sand, at 560 feet below ground surface, the tubes became very stiff and required an increase of pressure to lower them.

41. *Inefficacy of boring bar 50 lbs. in weight when worked in water 300 feet deep.*—As the boring was now getting deep, and the water in the tubes in the morning found to be over 300 feet in depth, it was absolutely necessary to lower the water in the pipes at least 100 feet before commencing the day's work on boring, as the boring bar, 50 lbs in weight, was found not to work satisfactorily in water 300 feet deep, the friction of the flat rope to which it was attached being much greater too, which reduced considerably the force of the blow that the boring bar would otherwise have delivered at each fall.

42. *Boring between 561 and $573\frac{1}{2}$ feet below ground surface: great rush of the silt.*—From the 1st to the 14th August 1878, strata Nos. 106 to 115, or a total depth of $12\frac{1}{2}$ feet, were bored through, sand chiefly being met with. The bore was always found choked with silt in the morning. After stratum No. 115, at $573\frac{1}{2}$ feet below surface, was reached, the bore on the following morning was found choked for a height of 38 feet from the bottom, 35 feet of sand from stratum No. 114, and 3 feet of gravel from stratum No. 115, the latter stratum permitting the sand from above it to be washed through by the force of the water rushing into the bore.

43. *Tubes lowered 1 foot by gravity on night of the 9th August 1878.*—On the night of the 9th August 1878, when the bore had reached 569 feet below ground surface, the tubes lowered 1 foot by their own gravity into stratum No. 112, which was of loose sand, 2 feet thick.

44. *Accident to 40th and 41st of 5-inch diameter tubes.*—On commencing work on the 15th August 1878, it was discovered that the 40th and 41st of the 5-inch diameter tubes lowered had disjointed at 528 feet below surface and broken; the breaking of these tubes is supposed to be due to an unequal pressure having been exerted by the screw-jacks; the pressure actually applied was about 12 tons only, or about $\frac{1}{4}$th (at 3 tons per square inch of section) the maximum admissible.

45. *Water-bearing stratum No. 117 reached at 574 feet below ground surface. Conclusion of boring operations.*—The broken tubes were removed and replaced by others by the 22nd August 1878, and stratum No. 117 of boulders and pebbles was reached at 574 feet below ground surface. On the 24th of the same month, after weighting the boring bar, which proved too light to be worked at this depth, the boring was carried down only 3 inches deeper. Continued efforts were made by weighting

the boring bar to pierce stratum No. 117 of pebbles and boulders, but without success. The bore was carried down 3 inches further, and all endeavours with the appliances available failing to force the tubes lower, they were allowed to rest here at 574½ feet below ground surface, which completed actual boring operations at Sabzalkot.

46. *Storage of machinery*—The results of the bore to 574½ feet below ground surface not having proved satisfactory, further boring to the proposed depth of 600 feet below ground level was abandoned; the machinery was removed to Rajunpur, there taken to pieces and stored for further use.

47. *Quality of water struck at 574 feet below ground surface.*—There was a plentiful supply of water in this pebble and boulder stratum (the thickness of which could not be ascertained), which rose to 223 feet below ground surface, but it was still brackish although it did not tarnish brass, as the brackish water from the old well did. Pumping at the rate of 156 gallons per hour, the level of the water fell to 290 feet below ground surface, or 66 feet below level of water in the old well. The outpost garrison drank this water, which was drawn up by a 5-inch dip pump made of $\frac{1}{16}$th inch sheet copper at the rate of 8 gallons in ten minutes; the pump was attached to a flat rope wound by a single purchase crab winch.

48. *Planked shoot for guiding dip pump into the bell-mouth at top of tubing.*—To facilitate the drawing of water from the bore for the use of the garrison a bell-mouth was fixed to the top of the 5-inch tubes, and a planked platform erected on a level with the top of the bell-mouth, and to guide the dip pump into the bore a shoot of planks fixed together was set up. A spare flat rope was provided, and an additional dip pump, so that two pumps could be worked together, the one descending empty whilst the other ascending full to the top, the rope passing over two pulley wheels of common wood, 3 feet in diameter, fixed to uprights.

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Detailed Section of the Sabzalkot Boring.

No. of Stratum.	Thickness of Stratum. Ft.	Depth below ground surface. Ft.	Nature of Stratum.
1	24	28	Coarse running sand.
2	9	37	Compressed sand.
3	6	43	Sand with slight mixture of clay.
4	3	45	Sand and clay.
5	9	54	Very coarse sand.
6	6	60	Hard clay and sand.
7	4	64	Coarse sand.
8	4	68	Coarse sand with small pebbles.
9	7	75	Sand with large pebbles.
10	10	85	Dark sand.
11	24	109	Fine sand compressed.
12	4	113	Very compact sand.
13	15	128	Fine sand compressed.
14	29	157	Clay and sand very compact.
15	17	174	Limestone boulders.
16	15	189	Clay and sand very compact.
17	10	199	Loose sand and pebbles.
18	17	226	Hard clay and sand.
19	24	240	Brown running sand.
20	7	247	Very stiff clay.
21	4	251	Very coarse sand.
22	16	267	Sand and clay intimately mixed.
23	8	275	Fine sand running.
24	11	286	Sandy clay, slightly red.
25	2½	288½	Very hard reddish clay.
26	3	291½	Very coarse sand.
27	10½	302	Sandy clay.
28	7	309	Very stiff sand and clay with a few pebbles.
29	½	309½	Running sand.
30	8½	318	Sandy clay.
31	2	320	Running sand.
32	8	328	Very stiff light-colored clay.
33	5½	333½	Sandy clay.
34	5½	339	Very stiff red clay and sand.
35	8	347	Sand.
36	4	351	Gravel with boulders.
37	7	358	Very stiff clay.
38	3	361	Very coarse sand.
39	½	361½	Red loamy clay.
40	3½	365	Light-colored clay.
41	1	366	Hard sand.
42	½	366½	Coarse gravel.
43	3½	370	Stiff clay with stones.
44	1	371	Sandy clay.
45	1	372	Coarse gravel and sand.
46	1½	373½	Blue and yellow clay.
47	1½	375	Stiff clay.
48	2	377	Coarse blue sand.
49	7	384	Clay and stones.
50	3	387	Gravel and boulders.
51	1½	388½	Stiff clay.
52	1½	390	Coarse blue sand.
53	15	405	Gravel and boulders.
54	1	406	Sandy clay.
55	4	410	Very coarse gravel and boulders.
56	8	418	Drift pebbles and sand.
57	3	421	Stiff clay.
58	1	422	Coarse sand pebbles, plenty water.
59	8	430	Clay.
60	2	432	Sand.
61	1	433	Clay; no water.
62	4	437	Fine sand; no water.
63	1½	438½	Clay.
64	2	440	Firm sand.
65	2	442½	Clay.
66	1½	444	Sand.
67	13	457	Clay.
68	3	460	Sandy clay.
69	9	469	Stiff clay with occasional layers of sandy clay.
70	2	471	Sandy clay.
71	11	482	Stiff clay with occasional layers of sandy clay.
72	6½	488½	Sandy clay.
73	1	489½	Clay.
74	1½	491	Sandy clay.
75	1	492	Sand.
76	3	495	Firm sand; water brackish.
77	4	499	Clay; no water.
78	1	500	Sand; water appears again.
79	26	526	Clay.
80	2	528	Pebbles and sand; water which rose to 224 feet below ground surface.
81	2½	530½	Clay.
82	1	531½	Pebbles and sand.
83	½	532	Sandy clay.
84	1	533	Fine sand.
85	3	535	Clay.
86	1	536	Sand and pebbles; water.
87	1	537	Clay.
88	1	538	Coarse sand and pebbles; water.
89	½	538½	Clay.
90	½	539	Sand and pebbles.
91	¼	539¼	Clay.
92	¼	539½	Sand and pebbles.
93	½	540	Clay.
94	½	540½	Sand and pebbles.
95	2	542½	Clay.
96	1	543½	Fine sand.
97	½	544	Clay.
98	2	546	Sandy clay.
99	1	547	Clay.
100	3	550	Clay and sand.
101	1½	551½	Clay.
102	2	553½	Sandy clay; water.
103	2½	556	Clay.
104	4	560	Sandy clay.
105	1	561	Firm sand.
106	½	561½	Pebbles and sand.
107	½	562	Clay.
108	½	562½	Loose sand.
109	3	565½	Clay.
110	½	566	Sand water.
111	3	569	Clay.
112	2	571	Loose sand.
113	½	671½	Clay.
114	1½	573	Loose sand.
115	½	573½	Firm gravel.
116	½	574	Clay.
117	½	574½	Pebbles and boulders; water.